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NOVEMBER 1939

WORLD PETROLEUM

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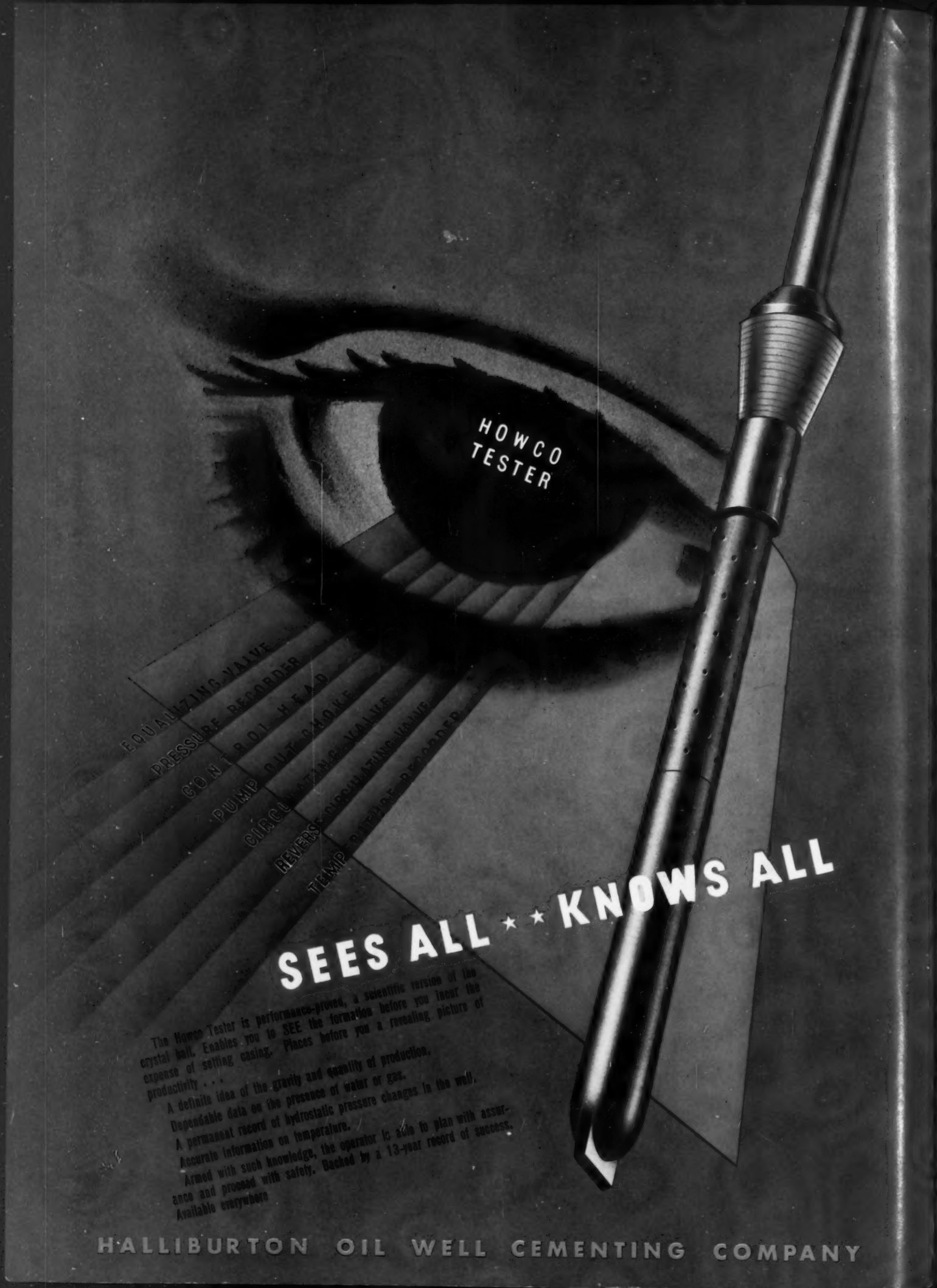
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WORLD PETROLEUM

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TANKER ON LAKE MARACAIBO

EDITORIAL

"ESSENCE AND REALITIES" NEED UNDERSTANDING

IN THE hearings upon the structure and operations of the oil industry just completed by the Temporary National Economic Committee in Washington some hundreds of thousands of words of exposition, argument and cross examination have been recorded. The volume of the testimony is so great that it is probable that few persons, even among the members of the Committee, will have the time or patience to digest it fully. The daily press reports have been able to do no more than to make brief and passing reference to the carefully prepared statements and, naturally enough, have given most prominence to controversial allegations and replies.

It cannot be said that the hearings have brought out anything that was new or unfamiliar to those acquainted with the industry. Most of the testimony traversed ground already covered very completely in the bulky proceedings of the Cole Committee 1934-35. The only connected and consistent picture of the industry's practices and problems is contained in the series of statements comprising a program worked out by the American Petroleum Institute at the request of the Committee. In these papers the various activities comprised in the exploration for oil, its production, transportation, refining and marketing, are described by men familiar with these different branches of the industry. Taken together they present a very complete and instructive record.

Criticism of the organization of the industry and of its methods consisted for the most part of threadbare charges that have been repeatedly made but never substantiated by those who have opposed every constructive move within the ranks of the industry. Many of these claims are mutually self-effacing. On the one hand it is asserted that the larger units in the industry are attempting to establish unduly high prices through monopolistic control; on the other complaint is made that competition is carried to such lengths that the existence of all except the financially strong is threatened.

While the task set before the committee was to assemble factual information as a possible basis for recommendations looking to the improvement of conditions within the industry or the better safeguarding of the interests of the public certain representatives of executive departments of the government appeared to be imbued with the idea that it was designed to bring an indictment against the major companies. The insatiable longing for continuous investigation and prosecution on the part of the Federal Trade Commission and the Department of Justice found expression in the proposal put forward by a representative of the former for a "complete" investigation of market practices, particularly those of the major companies. This is an exhausted subject if ever there was one.

THE various chapters of the testimony relating to the organization and operation of the industry show conclusively that the oil business is conducted with a high degree of efficiency, that it has continuously improved the quality of its products and lowered their cost to consumers, that wages and conditions of employment are highly favorable to workers and that, so far as is permitted by existing laws, the industry has striven to conserve national resources and avoid economic waste. That its record at times has been marred by needless price wars which have injured both producers and consumers does not alter its fine record of public service in other respects.

Perhaps the most cogent thought that found utterance on the part of committee members was that voiced by Commissioner Henderson in his final remarks when he said "the sooner the essence and the realities of this industry are understood the sooner the industrial problems can be dealt with on the one hand so far as business policy is concerned and on the other so far as government policy is concerned." Opinions may differ as to what are the essence and realities of the oil industry, but one truth must be acknowledged. Upon the interpretation which the committee places upon this statement will depend the value of its conclusions so far as the industry itself is concerned.

T N E C CONCLUDES OIL INDUSTRY HEARINGS

Testimony Reveals Nothing New but Provides Comprehensive Picture of Trade's Operations and Results—Summations Presented by Farish and Henderson.

ALTHOUGH the Temporary National Economic Committee, in four weeks of hearings, has completed its presentation of all phases of the petroleum industry, it cannot be said that the inquiry has produced any major reaction indicative of a line of agreement among the committee members upon which to base recommendations to Congress.

At the final session an exchange between Senator O'Mahoney of Wyoming, chairman of the Committee, and W. S. Farish, president of the Standard Oil Company of New Jersey, the closing witness, found Senator O'Mahoney who is an outspoken advocate of federal licensing of all industry in interstate commerce, apparently attaching importance to repeated assertions that the larger companies obtain their profits from pipeline control.

Previously, this view, and its elaborations, had been advanced by James A. Horton for the Federal Trade Commission in a survey of "controversial marketing practices in the retail phases of the petroleum industry." It was his conclusion that "a proper solution of the various problems of marketing cannot be made until a thorough and complete investigation had been made of the marketing practices of this industry, with particular reference of the marketing practices of the major oil companies."

When Senator O'Mahoney commented that the bulk of complaints made by the independents and the marketing associations were along this line Mr. Farish declared: "I don't for the life of me see how the government can take care of every business man who fails to make a profit."

Before the hearings were adjourned Mr. Farish and Leon Henderson, a member of the Securities and Exchange Commission, and its representative on T N E C entered detailed statements of their opinions on the broad aspects of the situation as related to legislative action and the development of the industry.

Explaining that he wished, for the minute, "to step out on my role as representative of the oil industry or as President of the Standard Oil Company" and make a few personal remarks about his reaction to the hearings as a citizen and "on the problem of full employment of men and capital" Mr. Farish said:

"With regard to these hearings let me say, that this was an experimental inquiry. It represented an effort to bring business and government into a friendly round table discussion of the genuine problems of the industry. It was a great opportunity for government to show business that public officials were more interested in developing facts and the full implications thereof than they were to obtain information to support some pet piece of legislation or some preconceived theory of economics or social reform. It was a chance for business to give a coordinated picture of its operation and policies without the 'I object' approach of counsel in the court room. This committee has an opportunity to make a real contribution toward establishing mutual confidence and respect between business and government, an accomplishment which would have more effect in putting men and capital to work than anything else you might do. Your great opportunity also involves a great responsibility to show the public that you have listened with open minds; that you are anxious to see the patterns in terms of their contribution to employment of labor and capital. In studying the patterns of American industry I expect that you will evaluate the services rendered to consumers by industry, especially the cost reductions which have made low prices possible.

"As a good Southern Democrat of long standing I am slow to approve drastic changes in government policies and principles. As a business man myself and also as a student of the reactions of business men, I urge you to consider the emotions and reactions of those who risk capital and employ labor. Do you realize that too drastic changes cause them to lose courage? Do you realize that once changes have been made—and there have been many in the past ten years—stability of direction is essential to the renewal of courage? If government would show more stability of purpose and firm adherence to principle, one great, if not the greatest obstacle to the full employment of men and capital would be removed.

"I hope, therefore, that your committee will review the real impact of government policies on uncertainty and their relationship to the will and ability of business to employ both labor and capital more fully."

Speaking apparently for the view held in some sections of the T N E C on existing conditions in the oil industry as regards competition Mr. Henderson said:

"May I point out some of the things which seem to me pertinent as to the general characteristics of that type of business organization of a gigantic industry. There seems to be no doubt that you get increasing stability in crude prices and you get a general acceptance by virtue of the nature of things, of a price leadership, a price leadership which it has been argued does not derive from any concerted action that is *in flagrante delicto* so far as laws are concerned.

"Undoubtedly there is communality of practice in a general acceptance in the industry of certain things which are alike in their action. The Iowa plan, for example, while not wide-spreadly accepted, was taken throughout the industry. In a number of cases the accounting practices and the restatement of stock following the logic of events seemed to come along about the same time.

"So for the attitude on conservation, pro-

W. S. Farish

ration, unitization, it seemed very definitely that the policies which are growing are likely to be those which favor a large amount of resources in the operating companies. And even if there should be another large discovery similar to East Texas, undoubtedly there would be state legislation which would follow fairly quickly, which would have as its aim some conservation or stabilizing effort.

"It seems to me, then, that we have got something quite different from the commonly accepted ideas of what produces free and complete market competition, and that the sooner the essence and the realities of this industry are understood, the sooner the industrial problems can be dealt with on the one hand, so far as business policy is concerned, and on the other hand so far as government policy is concerned.

"And I seem to sense running through the testimony a feeling that some of the business policies complained of are somewhat differently affected by the nature of the concepts of competition as they exist in this country, and as they are reflected in our laws relating to competition, and also as they are related to the existing laws regulating the oil industry."

Throughout the presentation the committee heard from witnesses that (1) there is plenty of oil in the United States for any emergency; (2) labor conditions in the industry are good and wages high; (3) twenty major integrated companies dominate the industry; (4) that the industry is and is not monopolized; (5) the independent is and is not being squeezed out; (6) there is no need for further federal regulation, (7) and the industry should or should not be regarded as a public utility.

Because of conflicting statements as to prices and apparent doubt as to exact cost of gasoline per gallon at the refinery gate there was suggestion of a recommendation to Congress for determining uniform cost and accounting practices in the industry. Coupled also was evidence that legislation might be advocated for closer federal-state cooperation.

This measure upon which Representative Cole of Maryland, chairman of the subcommittee handling the bill has promised hearings soon, was sent to Congress at the close of the last session and represents the views of the Department of the Interior on the problem.

RECORD ATTENDANCE Promised for Annual API Meeting

Gathering at Chicago Expected to Exceed all Previous Conventions in Numbers and Interest — Fifty Addresses and One Hundred Group Meetings Scheduled—Tax Conference to be Held.

THE annual general meeting of the American Petroleum Institute, which incidentally marks the twentieth anniversary of the founding of the organization, will be held at Chicago, November 13–17. In accordance with the Institute's tradition of making each year's gathering bigger and better than the ones preceding it is expected that attendance at the coming meeting will exceed all previous records. From advance indications it is estimated that over 3,000 persons identified with the various branches of the oil industry will participate in the two general sessions, the sixteen group sessions and approximately 100 committee meetings. More than fifty addresses are scheduled on the speaking program.

Contributing to an enlarged attendance will be the holding, in connection with the convention, of an interstate conference on automotive taxation sponsored by the American Petroleum Industries Committee. This gathering will be attended by tax authorities, state officials, automotive equipment experts and members of petroleum industries committees from twenty-eight states.

Another innovation will be the first annual reception and dinner of the industry's newly organized Twenty-five Year Club which will be held on the evening of November 14.

Aside from the interesting program laid out and the special features and events, the many unsettled conditions surrounding the industry at the present time will lead oil men from all parts of the country to turn their steps toward Chicago for the opportunity of discussing with their fellow members the general outlook for the coming year. The effects of the European war, the moves for further federal investigation and regulation and the uncertainties of the market situation are among the topics certain to receive much informal discussion. The chance to get together for the renewal of old friendships and to talk things over is one of the chief advantages of the meeting for many members.

Unusual interest attaches to the meeting of the Board of Councillors and to elections this year. Revision of the Institute's by-laws has placed membership of the board of directors at 110, plus ex-officio members comprising elected officers of the Institute, and a completely new board is to be elected on the basis of a revised schedule of representation. Eight national officers of the Institute, and forty members of production and refining divisional general committees, also are to be elected.

Guest speakers for the Institute's general sessions include Dr. Joseph E. Pogue, petroleum economist, of Chase National Bank, New York; Paul G. Hoffman, of the Studebaker Corp., South Bend, Ind.; Barclay Acheson, associate editor of Reader's Digest, Pleasantville, N. Y.

Speakers at the Interstate Conference on Automotive Taxation include Dr. Finla G. Crawford, of Syracuse University; Major Roy F. Britton, president, Automobile Club of Missouri; Francis Johnson, Iowa Farm Bureau Federation; State Highway Commissioner, Murray D. Van Wagoner, of Michigan; Ted V. Rodgers, of American Trucking Associations; Fred A. Eldean, Tax Foundation; Dr. Roswell Magill, of Columbia University; and Thomas H. MacDonald, of the U. S. Public Roads Administration.

Other speakers will be Chester H. Gray, National Highway Users Conference; William L. Ayers, Chicago Journal of Commerce; Norman S. Taber, public-finance consultant, New York; John D. Fitzgerald, of Columbia Broadcasting System; Dr. Gustav Egloff, Universal Oil Products Co.; Joseph L. McLaughlin, of the New Jersey Tax Department; Charles J. Yokom, of Detroit; Dawes E. Brisbine, of the National Highway Users Conference; and Conger Reynolds.

Subjects to be considered at group sessions include automotive-transportation economics, pipeline transportation problems, fuels and lubricants, public relations, drilling practice and technology, desulfurization and dehydrogenation, production practice and materials, alkylation and catalytic refining.

The preliminary program follows:

Monday, November 13

9:00 A.M.

American Petroleum Industries Committee

(State Chairmen and Secretaries Session)

Interstate Conference on Automotive Taxation

The Road Traveled and the Road Ahead.
B. H. Markham, American Petroleum Industries Committee, New York, N. Y.

Trends in Public Finance.
Dr. Roswell Magill, Professor of Law, Columbia University, New York, N. Y.

Highway Program for the United States.
Thomas H. MacDonald, U. S. Public Roads Administration, Washington, D. C.

12:30 P.M.

American Petroleum Industries Committee

(State Chairmen and Secretaries Luncheon)

2:00 P.M.

American Petroleum Industries Committee

(State Chairmen and Secretaries Session)

Interstate Conference on Automotive Taxation

The Gasoline Tax—Its Use and Abuse.
Dr. Finla G. Crawford, Dean of the College of Liberal Arts, Syracuse University, Syracuse, N. Y.

Highway Bonds and their Effect upon Taxes.
Norman S. Taber, Consultant on Public Finance, New York, N. Y.

Gasoline Tax Administration.
Joseph L. McLaughlin, Division of Motor Fuels, New Jersey Tax Department, Trenton, N. J.

The Farmer and the Highways.
Francis Johnson, Iowa Farm Bureau Federation, Des Moines, Ia.

The American Motorist and the Gasoline Tax.
Major Roy F. Britton, Automobile Club of Missouri, St. Louis, Mo.

8:00 P.M.

American Petroleum Industries Committee

Tuesday, November 14

9:00 A.M.

American Petroleum Industries Committee

(State Chairmen and Secretaries Session)

Interstate Conference on Automotive Taxation

Constitutional Safeguards Against Diversion.
Murray D. Van Wagoner, State Highway Commissioner of Michigan, Lansing, Mich.

Highway Barriers and the Need for Cooperation in their Removal.
Chester H. Gray, National Highway Users Conference, Washington, D. C.

Problems of Truck Transportation.
Ted V. Rodgers, American Trucking Association, Inc., Washington, D. C.

The Alcohol-Gasoline Proposal.
Conger Reynolds, Chairman, Committee on Motor Fuels, American Petroleum Institute, Chicago, Ill.

9:30 A.M.

Automotive Transportation

Transportation Economics

(Sponsored by the Central Committee on Automotive Transportation.)

Presiding: J. F. Winchester, Standard Oil Co. of New Jersey, New York, N. Y.

Address:
Dawes E. Brisbine, National Highway Users Conference, Washington, D. C.

Address:
Charles J. Yokom, Petroleum Transit Corp., Detroit, Mich.

Tuesday, November 14

12:30 P.M.

American Petroleum Industries Committee

(State Chairmen and Secretaries Luncheon)

2:00 P.M.

American Petroleum Industries Committee

(State Chairmen and Secretaries Session)

Interstate Conference of Automotive Taxation

Compulsory Gasoline Grading.

Gustav Egloff, Universal Oil Products Co., Chicago, Ill.

Newspapers and Good Public Relations.

William L. Ayers, Chicago Journal of Commerce, Chicago, Ill.

Broadcasting Your News.

John D. Fitzgerald, Columbia Broadcasting System, New York, N. Y.

2:00 P.M.

Automotive Transportation

Symposium on Meters

(Sponsored by the Central Committee on Automotive Transportation).
Presiding: H. E. Speer, Shell Oil Co., Inc., St. Louis, Mo.

Pros and Cons on Use of Meters on Automotive Equipment in the Delivery of Petroleum Products.

Discussion to be led by:

Walter W. Brown, Ralph N. Brodie Co., Inc., Oakland, Calif.

L. A. Carlson, Gulf Oil Corp., Pittsburgh, Pa.
R. F. Fike, Mid-Continent Petroleum Corp., Tulsa, Okla.

Allen A. Floyd, Smith Meter Co., Milwaukee, Wis.
L. M. Goldsmith, The Atlantic Refining Co., Philadelphia, Pa.

Frederick B. Hufnagle, Jr., Sun Oil Co., Philadelphia, Pa.

W. H. Marsh, Pittsburgh Equitable Meter Co., Pittsburgh, Pa.

J. F. Winchester, Standard Oil Co. of New Jersey, New York, N. Y.

2:30 P.M.

Board of Directors

Wednesday, November 15

9:00 A.M.

American Petroleum Industries Committee

(State Chairmen and Secretaries Session)

Interstate Conference on Automotive Taxation

The Need for a United Tax Front in the Petroleum Industry.

Russell B. Brown, Independent Petroleum Assn. of America, Washington, D. C.

Taxation and the Citizen.

Fred A. Eldean, Tax Foundation, New York, N.Y.

Round-Table Discussion.

10:00 A.M.

Board of Directors

10:30 A.M.

Board of Councillors

To nominate candidates for election as members of the Board of Directors.

General Session

2:00 P.M.

Presentation of Accident-Prevention Certificate Awards.

Report of Board of Councillors and Election of Directors.

President's Address:

Axtell J. Byles, American Petroleum Institute, New York, N. Y.

Address:

Hon. Wm. P. Cole.

Address:

Hon. Leon C. Phillips.

Address:

Paul G. Hoffman, The Studebaker Corp.

Thursday, November 16

9:00 A.M.

American Petroleum Industries Committee

State Chairmen and Secretaries Session

Round Table Discussion

9:30 A.M.

Division of Production

Pipe-Line Transportation Problems

(Sponsored by the Tropical Committee on Pipe-Line Technology of the Central Committee on Pipe-Line Transportation.)

Presiding: Walter F. Rogers, Gulf Oil Corp., Houston, Tex.

Internal Corrosion of Gasoline Pipe Lines.

L. C. Morris and W. A. Schulze, Phillips Petroleum Corp., Bartlesville, Okla.

Comparison of Tests for Determining Soil-Corrosion Rates.

Cooperative Problems in Cathodic Protection.

L. F. Scherer, The Texas Pipe Line Co., Houston.

9:30 A.M.

Division of Production

Symposium on Collapsing Pressures and Setting

(Sponsored by the Central Committee on Drilling and Production Practice and the Engineers' Subcommittee on Tubular Goods.)

Presiding: B. B. Wescott, Gulf Research and Development Co., Pittsburgh, Pa.

Papers on the following subjects now are under consideration by the Program Committee.

A Rational Expression for the Critical Collapsing Pressure of Pipe under External Pressure.

W. O. Clinedinst, National Tube Co.

Problem of Collapse of Deep-well Casing.

J. L Holmquist and A. Nadai.

A New Equation for Determining Collapse Strength.

Combining Hoop and Bending Stresses to Establish Casing Collapse Pressures.

W. C. Main, Los Angeles.

Thursday, November 16

10:00 A.M.

Board of Directors

The Executive Committee will meet immediately following the last session of the Board of Directors.

10:00 A.M.

Division of Refining

Fuel and Lubricants

New Thermofor Kiln and Clay-Regeneration Processes for Maintaining Decolorizing Clays at High Efficiencies.

T. P. Simpson and J. W. Payne, Socony-Vacuum Oil Co., Inc., Paulsboro, N. J.

Hypoid-Lubricant Requirements of Cars and Trucks.

H. R. Wolf, General Motors Corp., Detroit, Mich.

Cylinder Lubrication of High-Speed Diesel Engines as Influenced by Temperature and Combustion Process.

A. T. McDonald and L. A. Blanc, Caterpillar Tractor Co., Peoria, Ill.

Diesel-Fuel Specifications.

G. C. Wilson, University of Wisconsin, Madison, Wis.

Discussion by Engine Manufacturers.

10:00 A.M.

Public Relations

Public Relations

(Sponsored by the Central Committee on Public Relations.)

Presiding: W. S. S. Rodgers, The Texas Co., New York, N. Y.

The Philosophy of Industrial Relations.

H. H. Anderson, Shell Oil Co., Inc., St. Louis, Mo.

Helpful Petroleum.

W. D. Humphrey, The Ohio Oil Co., Findlay, O.

Public Relations in Advertising.

H. K. Boice, Benton and Bowles, Inc., New York, N. Y.

Thursday, November 16

General Session

2:30 P.M.

Address:

Victor H. Seales.

Address:

Joseph E. Pogue.

Address:

Barclay Acheson, The Reader's Digest, Pleasantville, N. Y.

Annual Dinner

7:30 P.M.

Friday, November 17

9:30 A.M.

Division of Production

Drilling Practice and Technology

(Sponsored by the Central Committee on Drilling and Production Practice.)
Presiding: M. Albertson, Shell Oil Co., Inc., Houston, Texas.

Viscosity Determination of Sub-surface Samples.

P. G. Exline and H. J. Endean.

Partial Volumetric Behavior of the Lighter Hydrocarbons in the Gas Phase.

B. H. Sage and W. N. Lacey.

Results of Pressure Core-Barrel Tests.

B. W. Sewell.

American Petroleum Institute-Bureau of Mines Pressure Core-Barrel Test.

Report of Division's Nominating Committee.

John A. Ritter, Sun Oil Co., Dallas, Tex., Chairman.

Friday, November 17

10:00 A.M.

Division of Refining

Refining Methods

Presiding: R. A. Halloran, Standard Oil Co. of California.

Petroleum-ization—1940.

H. W. Field, The Atlantic Refining Co., Philadelphia, Pa.

Hydrocarbon Research at Ohio State University.

D. P. Barnard, Standard Oil Co. (Indiana), Whiting, Ind.

Catalytic Desulfurization to Improve Aviation Blending Naphthas.

W. A. Schulze and R. C. Alden, Phillips Petroleum Co., Bartlesville, Okla.

Catalytic Dehydrogenation of Gaseous Hydrocarbons.

A. V. Grosse and V. N. Ipatieff, Universal Oil Products Co., Chicago, Ill.

Report of Division's Nominating Committee.

J. B. Rather, Socony-Vacuum Oil Co., Inc., New York, N. Y., Chairman.

Election of Twenty Members of the General Committee of the Division of Refining.

2:00 P.M.

Division of Production

Production Practice and Materials

(Sponsored by the Central Committee on Drilling and Production Practice.)

Presiding: P. D. Torrey, The Sloan and Zook Co., Houston, Tex.

Range of Application of Gas-Lift Methods.

E. C. Babson, Union Oil Co.

The Effect of Well-Bore Diameters as Observed in California Oil-Sand Reservoirs.

Ernest K. Parks.

Capacity Rating of Roller Bearings.

C. R. Athy, Int. Derrick & Equipment Co.

Protective Coatings.

C. F. Rassweiler.

2:00 P.M.

Division of Refining

Alkylation and Catalytic Cracking

Presiding: K. G. McKenzie, The Texas Company.

Thermal Alkylation and Neohexane.

G. G. Oberfell and F. E. Frey, Phillips Petroleum Co., Bartlesville, Okla.

Sulfuric-Acid Alkylation.

Anglo-Iranian Oil Co., Ltd., Shell Development Co., Standard Oil Development Co., and The Texas Co.

Catalytic Reforming for Production of Aviation Gasoline.

J. R. Bates and A. G. Petrikin, Houdry Process Corp., Philadelphia, Pa.

Catalytic Cracking.

A. V. Grosse, V. N. Ipatieff, Gustav Egloff and J. C. Morrell, Universal Oil Products Co., Chicago, Ill.

PRORATION ESSENTIAL to Efficient Operation

By Joseph E. Pogue

Regulatory Practices Are Advancing by Successive Stages Toward a Sound Engineering System Leading to Optimum Rates of Production and Maximum Recovery.

In spite of frequent attacks upon the methods adopted by state authorities in regulating production, proration itself has made steady progress and has won increasing support from members of the oil industry. In the following article by Joseph E. Pogue, leading petroleum economist, which was prepared as part of a study for the Temporary National Economic Committee, the theory and practice of proration is subjected to a searching analysis such as has not before been attempted. Mr. Pogue examines the conditions essential to conservation and shows how proration is gradually assuming a pattern based on sound engineering that will realize its fundamental aims. We believe his discussion will lead to a clearer understanding of this whole subject among oil men as well as among those outside the industry.—Ed.

THE wastes of oil fall into two groups: those visible above ground and those that occur unseen in the reservoir. The first class, prominent in the period of rapidly expanding demand, has been eradicated in recent years and, no longer presenting a problem, may be dismissed from further consideration. The second class, representing oil that fails to be recovered, is negative and unspectacular, but none the less important because indirect. This category is the proper field for attention and constitutes the real problem of conservation. Conservation formerly was concerned with the oil lost on the surface and the gas dissipated in the air, and there is still a tendency to think in those terms; but the practical elimination of above-ground waste leaves the problem of conservation centered in the restriction of losses in the underground reservoir itself.

"In the preparation era, wells were drilled densely and as rapidly as possible."

Above-ground losses of gas are still observable in certain areas, but are related to inadequate control of reservoir energy rather than to inefficient handling of the gas itself. Great volumes of gas have been blown into the air in the race to produce oil rapidly and this practice, while greatly lessened, has not been wholly eradicated. The waste of gas is spectacular and examples have been repeatedly publicized. Gas losses in our oil fields fall into two categories: the gas which must be produced with the oil and, lacking a market, is blown into the air or burned; and the gas which need not be produced with the oil but is so produced in order to increase the rate of oil production. At present the first class to a large extent is an unavoidable practice (else the oil must remain shut-in); the second class is a malpractice stemming from the rule of capture. The first class is in process of elimination through pressure maintenance, repressuring, and further developments in the natural gas industry;[1] the second class is subject to control through proper management of the underground reservoir and considerable progress already has been made in the retention of the surplus gas in the reservoir until its usefulness there is fulfilled.

ENGINEERING

It now becomes necessary to review the complex field of engineering developments in the production of oil and, by setting aside the less essential features, to emerge with a simple, clear-cut understanding of how an oil field should be produced. A volume could be written on the subject, but the essence can perhaps be condensed into a single paragraph.

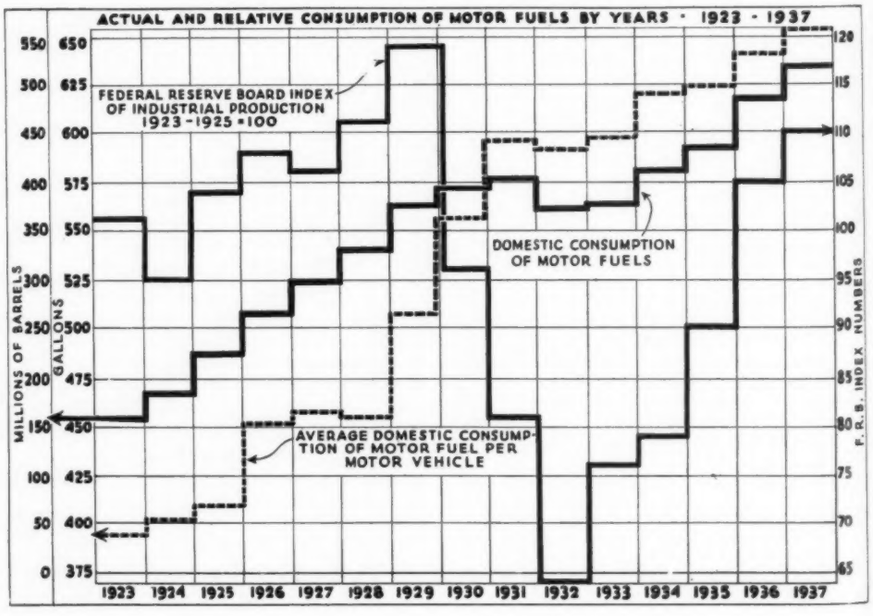
Oil occurs in underground traps in association with water and gas. The water underlies the oil and exerts a pressure on it. The gas occurs dissolved in oil and also, in some fields, as a gas cap overlying the oil. Both the pressure of the water and the expansion of the gas provide energy for moving the oil through the sand to the well and thence to the surface. The gas also has additional qualities: Its presence in solution renders the oil far more liquid than we know oil to be in its dead state above ground and in addition lessens the tendency of the oil itself to stick to the sand grains. It follows, therefore, that an oil pool should be so managed that the maximum utilization shall be made of the reservoir energy and of the presence of the gas itself, which usually means that the production should be restricted to a rate that will restrain the gas from coming out of solution in the reservoir and permit the oil to be replaced by the encroaching water.

In short, to obtain optimum recovery of oil from the reservoir, the rate of production must be regulated in conformance with engineering principles rather than left freely responsive to the dictates of demand or the competitive pressures of supply. The discussion could be lengthened to include the differences in behavior and operation of pools governed by hydraulic, volumetric, and capillary controls; while the management of the gas cap and the employment of methods of pressure maintenance, repressuring, and secondary recovery are also important. But these are specific problems in engineering and do not alter the general principles.

The optimum rate concept, it will be observed, concerns the individual oil pool; but a summation of the specific rates provides the optimum rate for each oil-producing state and in turn, for the nation as a whole. In order to effectuate the optimum rate in a given pool, two measures are necessary: limit the rate of production of the pool as a whole to that rate, as determined by engineering study, beyond which underground waste appears; and, if the field is competitively owned, impose upon the several operators the requirement that the oil be withdrawn ratably from each property, with due regard to the preservation of equilibrium within the reservoir as determined by bottom-hole pressure readings. In this way optimum recovery is assured, because the urge to produce is harnessed to engineering principles and each lease in the pool is enabled to subordinate the capture impulse to a co-ordinated action in harmony with the limitations placed upon the entire pool. The procedure, also, conforms to the principles of fair play and justice, for the correlative rights of each property owner are protected and equity is maintained.

It may be observed that the optimum rate objective is the goal toward which proration, in its evolution, has been groping and the degree of advancement in this direction appears to me to be greater than is generally realized. I see nothing in the way of a progressive attainment of this practical ideal of oil conservation unless it be failure on the part of social and industrial management to envisage the nature of the problem.

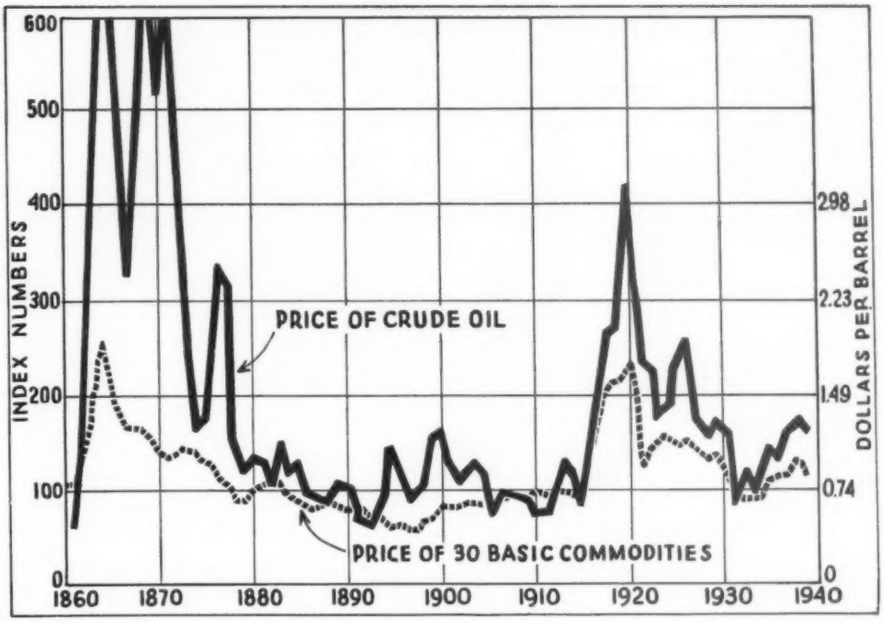
The approach to oil conservation involves two lines of effort: the furtherance of technical knowledge through engineering research to provide the technique for augmenting the

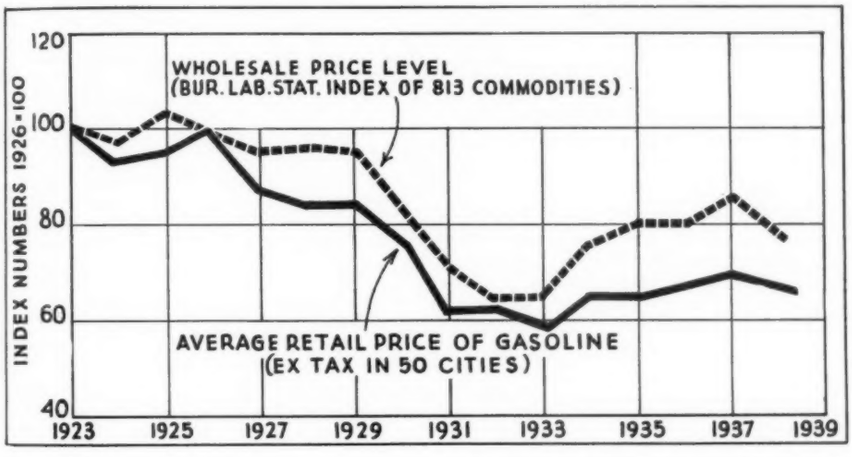

ACTUAL AND RELATIVE CONSUMPTION OF MOTOR FUELS BY YEARS · 1923 - 1937
FEDERAL RESERVE BOARD INDEX OF INDUSTRIAL PRODUCTION 1923-1925=100
DOMESTIC CONSUMPTION OF MOTOR FUELS
AVERAGE DOMESTIC CONSUMPTION OF MOTOR FUEL PER MOTOR VEHICLE
MILLIONS OF BARRELS
GALLONS
F.R.B. INDEX NUMBERS
550 500 450 400 350 300 250 200 150 100 50 0
650 625 600 575 550 525 500 475 450 425 400 375
120 115 110 105 100 95 90 85 80 75 70 65
1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937

[1] For the background of this problem, see Pogue, Opportunities and Responsibilities of the Natural Gas Industry Paper, American Gas Association, October, 1938.

utility of the resource; and the development of an adequate concept of action in order that an effective procedure may be established. Technical understanding is an automatic resultant of a vigorous, mass-production industry, and the achievements in this field have not only been noteworthy but are, in fact, ahead of their full application in the economic sense. A function of the capital employed and activated by the integrated structure of the industry, the factor of technology presents a dynamic aspect that assures its availability in ample measure. The problem of conservation, accordingly, boils itself down to the construction of a single design: a production practice that will result in the optimum recovery of oil from the reservoir at a rate conforming to the requirements of society. The term "optimum," frequently used in this analysis, carries the implication of a price-cost relationship that will maximize the usefulness of the resource to the consuming public.

Thus the thesis of oil conservation, in a practical sense, centers around the rate at which oil is produced. Control the rate properly, and conservation of oil becomes an accomplished fact. Since frequently as much as two-thirds of the oil is left behind in the sand under open-flow operations, wells must be throttled below capacity if waste is to be avoided. But before restricted operations are feasible, an extra capacity must be developed and the conditions leading to the building up of this margin are indistinguishable from overproduction. Therefore it appears only natural that conservation was ushered in by a period of overproduction.





Note that while the price of crude has in general exceeded comparable raw materials, gasoline prices have run below those of average commodities.

ECONOMIC STABILITY

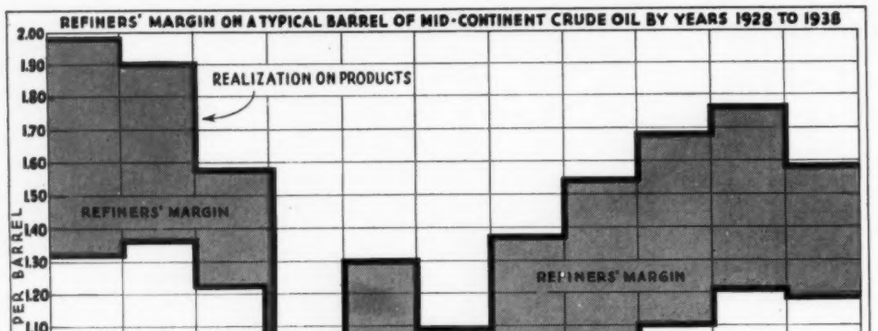
Crude petroleum naturally has a substantial range of costs because of the varying nature of its occurrence. Some oilfields are shallow, while others are deep-seated; some have thick sands under high pressures and yield their oil easily, others are in tight sands and give up their oil reluctantly. These conditions are not subject to control. But there is an additional factor—an unregulated rate of production—that distorts costs, creating extraordinarily low costs in the flush period and correspondingly high costs thereafter. Accordingly the rate element, under conditions of flush production, imposes a cost latitude that exceeds that of all other commodities and disturbs the function of price as an equilibrator of supply and demand. The costs of producing oil in a given field range all the way from a few cents a barrel in its flush stage to upwards of a dollar in its settled stage. Therefore oil from flush fields, divorced from the dictates of full costs and subject only to the influence of temporary out-of-pocket charges, can be sold for less than the bulk of production; and if in sufficient volume this component disrupts the stability of the industry.

Flush production is wasteful of reservoir energy while restricted flow is the essence of conservation. Wasteful practices in producing new oilfields result in lower current costs although they raise substantially the ultimate cost of the oil and reduce the total recovery. The economic pressure to convert an oil reserve into cash, especially in the presence of divided ownership under the influence of the rule of capture, encourages a policy of haste and waste from which there is no escape except through the imposition of artificial restraints under proration or voluntary control under unit operation. Cost competition is a desirable matter where such is a function of efficiency, but if low costs are attained at the expense of waste and an aftermath of higher costs, then the competition becomes destructive and antisocial.

It has been emphasized that waste can be avoided only by flowing an oil pool at a restricted rate. But when we reduce the rate of flow, we narrow the cost range; that is, we smooth out the cost curve. And when the cost curve is smoothed, the price curve is flattened. This principle observable in the single pool holds for the country at large, if fields in the aggregate are restricted. An important relationship accordingly comes to light: Conservation practices *per se* have a leveling effect upon costs and hence exert a stabilizing influence upon price. This inescapable result is a by-product of an act necessary on the grounds of conservation alone. As I see the matter, it is a very happy circumstance that those measures best calculated to prevent waste at the same time contribute to economic stability.

Even if costs and prices are smoothed by the effectuation of optima in production rates, however, there is still left a residual element of instability arising from the cost disparity between pools efficiently produced and the tail-ends of old fields. This statement poses the familiar stripper well problem. According to a cost study for the period, 1931–1934, conducted by the Department of Interior,[2] it

[2] Petroleum Administrative Board, Report on the Cost of Producing Crude Petroleum, Washington, Dec. 1935, Table 13.



was shown that 10.41 percent of the oil reported had a cost range of 0 to 39 cents a barrel; 49.95 percent, a cost range of 40 to 79 cents a barrel; 25.04 percent, a cost range of 80 to 119 cents a barrel; and 14.60 percent, a cost range of $1.20 to $4.40 and above a barrel. The extent of this cost range could be lessened under an optimum-rate limitation for production, but there is no escaping the fact that there will always be stripper wells. They are high-cost, marginal sources of supply which must eventually be abandoned upon economic exhaustion. Wells of this type have been accorded public attention because of the plausible plea that their abandonment means permanent loss of an important oil reserve, although the oil in most cases will still be available if operations are resumed. Ordinarily wells can be shut in for long periods without loss of reserves, while proper abandonment practice leaves the oil available for secondary methods of recovery. The importance of the stripper-well argument will decline, however, under optimum-rate control of flush fields, for the properly-produced oil pool will leave a less persistent legacy of stripper wells, thus rendering the unrecovered reserve in the stripper stage of less relative importance than it is today. Price collapses have usually been the causes for the abandonment of stripper areas, rather than persistent declines in physical production to very low levels; whereas the smoothing of prices induced by conservation will make virtual physical exhaustion, as it should be, the major determinant for relinquishment.

PRORATION

Proration has been described in a single phrase: "No more gushers." The process may be visually grasped by looking at a 1/8 in. choke and realizing that this small perforated steel billet, inserted into the flow line of an oil well bears down its rate of flow so that more oil is ultimately recovered, the flowing life is prolonged, and the cost curve is smoothed.

The conditions that gave rise to proration go back to the early post-war period when supply began to outdistance demand. Previously there had been periods of overproduction, but they were episodic and short-lived under the forward surge of consumption. But the conjuncture of revolutionary changes in the art of oil-finding with maturing demand brought on a setting in which overproduction took on a chronic aspect. For a while this new situation was met by adding the surplus to storage, but when this expedient ran its course, resort was had to the curtailment of key areas in the hope thereby of re-establishing a balance. The early steps were taken locally and tentatively, with no thought that a new operating form was under construction; but as additional fields came in the practice spread, the conservation laws of the states were invoked, and the procedure gradually became institutionalized and systematic organs of administration were developed.

As it now stands, proration is a planned production measure involving waste prevention, ratable takings, and a balancing of supply and demand, behind which stand the principles of conservation, equity, and stabilization. The procedure is administered by state regulatory bodies through use of the police power of the states under the authority of state conservation laws; and the federal government has accorded its co-operation by providing advisory quotas, circumscribing imports, checking movements of hot oil in interstate commerce, and ratifying an interstate oil compact. In the course of the past twelve years this regulatory system has become an institution with a framework of laws, court decisions, administrative bodies, trade practices, and traditions. The oil industry has come to be dependent upon proration and cannot be operated efficiently without it.

EQUILIBRIUM

Proration was launched as a measure for averting the economic consequences of overproduction. The primary motive for its application was undoubtedly economic, with the conservation aspect invoked as a basis for its establishment. This historical sequence has strongly colored current thinking on the subject and proration has come to be widely regarded as merely a production control. But whatever the nature of its impetus, proration has turned out to be a cardinal move toward conservation. The industry wrought better than it knew, better indeed, than it realizes now. Let me make this point plain:

The only way to maximize oilfield recovery is to restrict the flow. Likewise the only way to suppress overproduction, if it appears, is to do the same thing. Yet the only condition under which recovery can be maximized is one where there is sufficient potential supply to admit of its curtailment to an efficient rate. Therefore, once there is surplus-producing capacity in terms of wide-open operations, we cannot restrict the flow without preventing underground waste; contrariwise underground waste cannot be prevented without restricting the flow. Proration, accordingly, is by its nature a conservation measure as well as a production control. The only question in this regard is the relative emphasis to be placed upon each factor and whether, indeed, the two elements can be dissociated in practice.

Proration, started as a production control linked with waste prevention, is now a conjoint conservation measure and production control, and its trend is toward a preponderance of the conservation function. What is taking place is that the petroleum industry is in the course of making a transition from a condition of balance between demand and open-flow supply to a new plane of equilibrium between demand and optimum-rate supply. The passage is made feasible by the procedure or plan called proration.

QUOTA SYSTEM

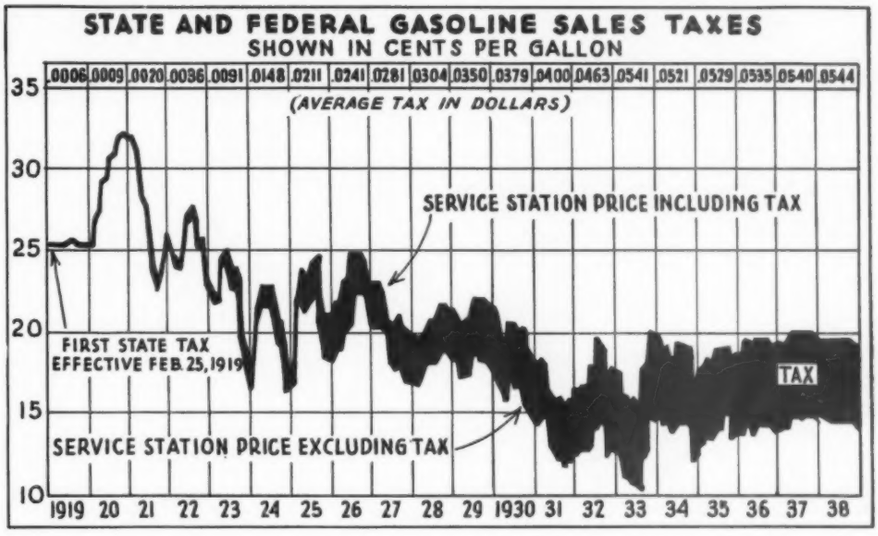
The conservation of oil involves two objectives: the restriction of flow to prevent physical waste, and the enforcement of ratable takings, or proportionate withdrawals, among the operators in the single pool, to preserve underground equilibrium and conform to the dictates of equity. Throughout the process the requirements of equity must be harmonized with the physical objectives, and the fairness of the adjustments is under constant review by the courts. Proration as practiced embraces identical principles and dictates, but at the same time attempts to make the system workable by measuring demand and fitting the varying components of supply to this factor. The machinery for accomplishing these ends involves the use of a quota system in which it is sought to bring into accord the requirements of waste prevention and market demand; but the efforts to reconcile the prescriptions of conservation with the exigencies of the market create problems of great complexity, involved in aspect, and difficult to resolve.

If each pool were limited in output to its most efficient rate of flow and ratable takings within each pool were enforced, then the primary objectives of conservation would be realized; but supply and demand would not balance in all their ramifications because prior investments are not in conformance with this

pattern. Moreover, the components of supply and demand are in course of continuous change and a balance once attained would itself tend to alter, thus indicating the need for a flexible procedure capable of sustaining a moving equilibrium characteristic of a dynamic economy. Price, of course, is normally the most effective regulator of supply and demand; but for special reasons, as we have seen, the supply factor in oil must be regulated. If a set of inflexible rules, however, were suddenly imposed and enforced, a condition of disequilibrium would result, disruptive of economic stability and destructive of progress toward conservation. As a pragmatic matter, accordingly, the progression toward the desired objectives, having its inception in a period of overproduction and unbalance, must proceed gradually and allow time for the necessary adjustments, not leaving the entire process of equilibration to price alone but supplementing this agency with the support of a program of restriction that bears some relationship to the geographic disposition of the reserve and the existing pattern of trade channels. Once, however, the critical adjustment has been accomplished—and this adjustment is still going on—the dependence upon quotas keyed to market demand can give way to engineering quotas more exclusively dictated by the supply factors.

On grounds other than interim expediency, there are practical arguments for the market-demand measurement. In a given pool, let us say, there is a market outlet for 30,000 barrels a day, whereas the pool, as determined by engineering study, can efficiently produce 60,000 barrels a day. The regulatory authority is charged with the responsibility of seeing to it that the pool does not exceed the 60,000-barrel optimum, but at the same time must require that any smaller production be withdrawn ratably. As an administrative matter, therefore, the state authority feels compelled to establish a market-demand quota for 30,000 barrels, subject to change from month to month if the demand alters as revealed at official hearings. And once the utility of a market-demand quota is conceded for the single pool, then the principle becomes established for the totality of pools and a nation-wide market-demand quota system comes into existence. As a matter of fact, the allowable production of each state and in turn for the nation as a whole is but a summation of the allowables of the component pools, arrived at after consideration of the local conditions surrounding each unit. The market-demand quota system is thus constructed from the bottom up, instead of being imposed from the top down, which is an important distinction; for the system is keyed to the source where it can be accorded flexible consideration in its manifold and shifting parts. The application of the advisory quotas, calculated by the U. S. Bureau of Mines, is that of a co-ordinating yardstick to permit the state regulatory bodies to visualize in advance the probable bearing of their respective actions upon the general situation.

Accordingly, despite the risks of maladjustments arising from the mishandling of the market-demand factor, the inevitability of market-demand proration must be accepted for the present. This aspect of proration may be eventually dispensed with, or at least greatly minimized in its incidence, but the time is not here when this can be done. The market-demand instrumentality must continue to be utilized but, to be sure, with greater regard for the proprieties of a moving equilibrium.


STATE AND FEDERAL GASOLINE SALES TAXES
SHOWN IN CENTS PER GALLON
.0006 .0009 .0020 .0036 .0091 .0148 .0211 .0241 .0281 .0304 .0350 .0379 .0400 .0463 .0541 .0521 .0529 .0535 .0540 .0544
(AVERAGE TAX IN DOLLARS)
35
30
25
20
15
10
SERVICE STATION PRICE INCLUDING TAX
FIRST STATE TAX EFFECTIVE FEB. 25, 1919
TAX
SERVICE STATION PRICE EXCLUDING TAX
1919 20 21 22 23 24 25 26 27 28 29 1930 31 32 33 34 35 36 37 38

Interestingly enough, practically all the objections to proration arise from the application of a market-demand quota system. These objections are brought forward on several counts: that the system interferes with the free play of supply and demand; that it is not wisely and fairly administered; that it does not create stability. This mechanism certainly offers opportunities for favoritism and abuse in its administration, but the same is true of all administered systems. It might even be said that a system of free economics favors the flush field and is "unfair" to the marginal operator. For my part, while recognizing the difficulties of administering a system based upon market demand, I find it difficult to see any practical way in which this phase of proration can be dispensed with until a new equilibrium is attained centering about a plane of demand balanced with optimum-rate production, and even then the equilibrium will not be static but in continuous course of change. That objective, of course, is being measurably approached, but until reached the specific problem is one of improvement and intelligent direction of the existing arrangement in the presence of a free market structure.

DRILLING

In the development of the administrative aspects of proration, the creation of means for bringing about equilibrium between drilling rates and production rates has lagged behind the progress made in other directions and hence a maladjustment has appeared which calls for correction. In the pre-proration era, under the reign of the rule of capture, wells were drilled densely and as rapidly as possible, for in no other way could the production from a single property, as contrasted with the pool, be maximized, although equal speed and well density on the part of all operators in the single pool cancelled out the individual advantage. With the establishment of proration, however, two new factors appeared: It was discovered that the conservation of reservoir energy was a partial substitute for drilling, since under back-pressure methods fewer wells are needed than under open-flow practice; and it became apparent that if the rate of production is to be restricted and therefore the pay-out period lengthened, then a concomitant spreading out of the investment period should likewise be provided for. Both of these considerations in the course of the past few years have entered the consciousness of operators, and have even received the cognizance of the regulatory bodies, as exemplified in well spacing rules in many pools and insistent discussions of the subject at commission hearings. But by and large, the drilling concept is less advanced than is desirable; and the principle that the state fails to do equity if it compels deferment in oil withdrawals without at least making it possible for the operator to retard his investment commensurably is yet to be established, although the matter appears to be getting close to that stage.

As a result of this unadjusted element in the handling of proration, unnecessary wells in great numbers have been drilled in the past few years and the allowable production per well has declined to the point where the whole subject is coming in for active attention.[3] Expressed in other terms, production has been largely divorced from the effects of the rule of capture, but drilling has not been freed from this influence in equal degree. In the administration of proration, the well, rather than the underlying oil reserve, has usually been accepted as the ultimate unit for allocation of demand. This policy creates artificial incentives not only for drilling more

(Continued on page 46)

[3]See Pogue, Economic Aspects of Drilling, Bull. Amer. Petr. Geol., Vo. 22, June 1938. pp. 633-644.

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Petrol Pool Commenced Operation Smoothly but Fear is Expressed that it May Lead to Establishment of Government Monopoly at Termination of War—Serious Setback Sustained by Automobile Trade.

ENGLAND'S WARTIME
Control Of Petroleum Distribution

By Alec H. Day

BASED upon carefully preformulated plans, the recent war-time pooling and rationing of Britain's petroleum supplies present a strong contrast to the situation at the outbreak of the 1914-18 war, which the country entered with completely free economy. Subsequent government control of the oil trade and finance then was a gradual and piecemeal development. Times have changed during the past twenty-five years, and present war-time control, instead of being applied in gradual stages, commenced with full force in this and many other industries at the very beginning of the conflict.

Control of oil importing and distributing has been left largely in the hands of the trade itself. Plans for the pooling of all major petroleum products were made by the importing and marketing companies long before the outbreak of war at the request of the Government, and were based on the scheme brought into operation in the later stages of the 1914-18 war.

Rationing control by divisional officers of the Petroleum Department is under the directions of the Mines Department. Employees engaged in Pool work are loaned by the various unit companies. In addition each unit has a staff working on domestic business.

Importation of oil products is left entirely to constituent companies, the distribution end of the industry being handled by the Pool. Quotas of the various distributors for providing supplies to the Pool are based approximately on the respective market quotas held during the year prior to the outbreak of hostilities.

All the country's requirements, including those of the fighting services, are supplied by the Pool, but in the first stages the main functions of pooling have been the distribution of motor spirit for private motoring and commercial transport under the rationing scheme.

Four weeks after the Petrol Pool went into active operation, the Lubricating Oil Pool made its official start, and all stocks were taken over and pooled. Specifications for 30 basic lube oils drawn up by a technical committee have been issued. These range from engine oils to medicinal white oils and petroleum jellies, and prices have been issued to the trade, to be followed shortly by retail prices. During the duration of the war there will be no branded motor oils on the market after present stocks have been sold.

A number of independent petroleum marketers have expressed the fear that after several years of pool operation—if the war lasts that long—the Pool will eventually become a post-war monopoly, and that the United Kingdom will cease to be the world's second largest free and competitive market, and that steps should be taken now to ensure legally that the Pool is dissolved within six months following declaration of peace.

Rationing, by which Government control has been applied to motor spirit retailing, was introduced on September 3 by a Board of Trade Order made under the Emergency Powers (Defence) Act, passed by Parliament just before the outbreak of war. Prompt control measures thus taken contrast sharply with oil policy in the last war, when no question of economy in the use of motor spirits was raised until the beginning of 1916, and then not by the Government but in the public announcement of a major distributing company. Two years of war had elapsed before motor spirit licensing actually came into force. Yet world production of oil was only 433,925,000 bbl., compared with approximately 2,000,000,000 bbl. today, and there are now far more tankers available. Britain's customs' releases of petroleum products in 1914 were 18,520,000 bbl. compared with about 65,000,000 bbl. in 1938, but the latter figure does not include oil for Government uses.

As now adopted, rationing has meant the disappearance from the market of previously well-known individual brands, and the sale only of "Pool" spirit to the public and commercial consumers. Pool spirit is described by the trade as a good mixture. It consists of about 25 percent of first-grade spirit of an octane rating between 70 and 80, and 75 percent of commercial spirit of about 66-68 octane.

Quality of Pool spirit may be accepted as reasonably good. No really poor quality spirit is sold in Britain nowadays, present No. 3 being generally reckoned as good as the first grade of five years ago. Nevertheless, the new motor fuel has not entirely escaped criticism from motorists, indifferent starting being one of the main objections raised. With many cars carbureter adjustment is necessary.

Probably due to the swift manner in which the Pool commenced to function, the question of tetraethyl lead was passed up temporarily as not being of great urgency at the outset. Possibly as the weeks go by this subject will be given the greater consideration that it deserves in view of the fact that so many motorists own modern high compression cars, and particularly because of the very slight additional cost involved. The present octane rating of 66 to 68 can easily be brought up to 72 by the addition of lead, and it is doubtful if the extra cost will exceed 1/4d. to 1/2d. per gallon. Should the introduction of lead be generally adopted all the petrol will be colored before the dealers are supplied. Motorists are

already paying 2d. a gallon more than they were at the formation of the Pool, and will undoubtedly have to stand another increase very shortly, and it is only right that they should be given a higher octane spirit if it can be done without further substantially increasing the cost.

At 1s. 6d. per gallon Pool spirit was priced at a figure midway between the 1s. 7d. charged for No. 1 and the 1s. 5d. for No. 3 just before war broke out. The price may have appeared unfavorable to the buyer on the basis of pre-war import costs, but was soon made to look very reasonable by the rapid rise in Gulf prices, tanker freights and insurance charges immediately after the war had started. A rise of 2d. per gallon has been made since and a further advance may become necessary.

Right, squeezing the last drop out of the hose on the day rationing began. Below, preparing alternative transport in Clapham Road.

© British Combine

Bulk prices to commercial buyers were also fixed originally at what has since seemed a low level, the prices operative at the beginning of September being left in force at the outset of the rationing scheme. Here again there must be a big saving in sales cost to petrol marketers.

Rationing is enforced by the Government compelling all users of motor spirit to obtain ration books, covering a fixed period and containing coupons authorising the purchase of a given amount of Pool spirit. The sales unit represents one Imperial gallon for motor spirit and two-thirds gallon for Diesel oil.

Motor Spirit Allowance for Private Cars

Rated Horse-power	Units (Gallons) per mth.
Up to 7	7
8 to 9	5
10 to 12	6
13 to 15	7
16 to 19	8
20 and over	10
Motor cycles	2

Supplies in excess of the ration can be obtained in special circumstances by application to a Divisional Petroleum Officer. There are sixteen of these officials around the country, so that considerable variation of policy regarding allotment of supplementary allowances is inevitable.

An official appeal to motorists to avoid unnecessary applications for supplementary rations was issued when rationing was introduced, and there is every reason to believe that this request is being generally observed. Many cases have occurred, however, in which additional supplies have been obtained on very slender grounds, not by wire pulling or personal influence, but by the simple method of putting in applications supported by flimsy reasons.

On the other hand the United Commercial Travellers Association has pointed out to the Mines Department that the allowance of sufficient petrol to drive 200 miles a month above the normal ration is quite inadequate and that 50,000 travellers will be thrown out of employment.

Motor spirit economy required of commercial transport is very much less than that expected from the private motorist. The government has stated that a saving of only 25 percent of estimated peace-time consumption by commercial users will be necessary. Basic rations for commercial vehicles have been calculated to give all such vehicles an equal mileage, which is equivalent to 50 per cent of the normal demand for spirit for commercial transport. About 50 percent of normal is expected to suffice for a large proportion of commercial car owners carrying their own goods. General road haulers may require relatively large additional rations, and a further 25 percent of total normal commercial consumption is reserved mainly for this purpose.

For purely agricultural purposes, farmers can obtain gasoline and Diesel oil with reasonable freeness, but for their private cars and for their lorries the regular rationing scheme applies, although farmers can apply for supplementary allowances.

Rationing has raised many complaints from owners of commercial transport, but criticism is directed less to the scheme itself than to the way it is being operated. As an allotment is on the basis of so much per individual vehicle and issued against its license number, a user, for example, is compelled to spread his allowance over his whole fleet of vehicles, instead of being allowed to draw fuel for all his vehicles and operate only a part of them. This is one of many directions in which the working of rationing of commercial transport may require overhauling and modifying.

Geoffrey Lloyd, Minister of Mines, informed Parliament that no retail stations have been taken over by the Pool, but a small number of service stations owned by small oil companies continue to supply commercial users only on the same conditions as before the Pool was formed.

Aside from the officially estimated cut of 25 percent in commercial consumption, rationing has caused a severe decline in the demand for motor spirit. Trade estimates put the falling-off in demand for private motoring at over 50 percent in the first few weeks of the operation of the scheme. In the county of Surrey alone about 5,000 motorists are reported to have surrendered their car licenses and stored their vehicles.

Demand for the fighting services has not yet made good the reduction in consumption

© British Combine

Sixty m. p. h. paraffin burning, steam driven, home made car escapes rationing restrictions in Leek.

due to rationing and to the great drop in night driving, although in circumstances of great military and air activity the position might be completely changed. Training and other preparations were already using large quantities of petroleum, so the difference between war and peace requirements for government operations has not had time to equal the sudden drop in private and commercial uses.

Operating on the ration allowance, the average private car in Britain has a mileage of 160 to 180 per month, or about 2,000 miles a year. Estimates prepared by the Royal Automobile Club put the minimum distance covered by the normal private motorist in peace-time at 5,000 miles a year, and the average mileage at 10,000.

Average mileage under rationing, apart from supplementary rations, will thus be about one-fifth of normal. Undoubtedly, many motorists will find their annual mileage reduced to one-tenth of normal if they are to continue to rely on the originally fixed ration. The nation-wide black-out order also has made a tremendous difference to the volume and mileage of night driving by private cars.

From the viewpoint of Britain's 2,000,000 motorists, such a reduction opens a very serious prospect. Car tax, insurance, and some part of maintenance and depreciation, must be classed as irreducible overheads that cannot be cut down, however small the annual mileage. When mileage is inordinately curtailed by rationing of motor spirit, therefore, the overhead cost per mile becomes prohibitive. Motoring, which was becoming an ever-increasing necessity in British business, professional and private life, has thus been turned by rationing into an expensive luxury. In fact, the official attitude towards car operation in wartime other than that for urgent uses, seems to be that it is a luxury.

Such a change could have only one result. Cars are already being laid up in large numbers, and will undoubtedly be relinquished still more extensively in the New Year when the rise in the horsepower tax will become effective.

Rationing is having a devastating effect on the motor trade. Second-hand cars, originally costing £200 only a year or so ago, have been selling for around £10, and it is predicted that a used car will have no value at all by the end of the year. Sales of new cars have suffered a terrific slump, and the various motor driving schools are doing extremely little business.

Reactions from such a position on the motor manufacturing industry must be serious. Any set-back in the demand for heavy commercial vehicles will doubtless be made good to a considerable extent by government orders; but makers of lighter cars will be hard hit. Apparently they must look to new types of government work to keep their plants running, and that can only be achieved at the cost of great disorganisation and loss of earning power. If the war lasts for three years, British motor car design is likely to lag well behind American automobiles and so cause loss of export trade.

On broad national grounds the release of labour and plant for Government war work unquestionably is desirable, and probably essential, but the results of petrol rationing, and the consequent upheaval in the motor and garage industry will not be advantageous from numerous other aspects.

Rationing probably has been unnecessarily drastic, though this of course could not be forseen. Enormous storage schemes were carried through before hostilities started, and the failure so far of the German submarine campaign suggests that new imports have not been seriously checked. Only five tankers have been reported sunk at the time of writing. Some British oil men have drawn the conclusion from the holding-up of inward shipments that storage was, in fact, filled to overflowing at the beginning of September.

That does not mean that the pooling and rationing system will not need care in operation if it is to be completely successful. Retail storage will have to be handled very efficiently if waste of storage space is to be avoided.

Filling stations at present can only obtain new supplies of spirit on production of coupons representing spirit already sold to the public and after sufficient coupons have been accumulated. Their storage tanks will always remain partially empty except just after they have been replenished. Some garages having stocked in advance more supplies than their customers' coupons will use, have sold petrol to motorists in excess of their coupons; but, the garage tanks will only be replenished to the extent of the coupons presented, and in such cases will not again be full. A certain amount of waste storage is thus inevitable, and may amount in the aggregate to a large gallonage if filling station proprietors in their desire to delay expenditures allow too many coupons to accumulate in their hands without taking immediate steps to have their tanks refilled.

Storage waste of a more serious and permanent kind will probably result at a later date from the closing of retail filling plants. Many already are closed, and few remain open after dark. If the reduction in the use of cars, resulting from drastic spirit rationing, is on anything like the scale now threatened, many filling and service stations will be driven out of business. In fact, large numbers of employees have been discharged. Further development of this movement will put a large aggregate amount of storage out of action, possibly at a time when urgently required should an enemy submarine campaign or aerial attack prove more successful.

For the moment supplies in the country are almost super-abundant; but distributors and the public are bearing restrictions with good grace, although they realise that on current supply grounds alone heavy rationing is unnecessary. One other feature which is reducing consumption is the commandeering of thou-

sands of light lorries and cars for ambulance work, and large numbers of taxis for auxiliary fire service, and during the weeks of waiting these vehicles are running comparatively few miles, whereas their normal industrial consumption would be heavy.

Drastic limitation of consumption is probably due to a desire to husband foreign exchange resources rather than to any immediate fear of a shortage of motor spirit. Exchange presents one of the country's outstanding war-time problems; yet, of course, a

© British Combine

Above, British Broadcasting staff transferred to the country use bicycles to conserve petrol while the 432 cu. ft. of gas (right) carried atop the lorry are equivalent to two gallons of petrol.

nation must buy as well as sell as a part of international economics.

Britain started the war of 1914-18 as the world's greatest creditor country, but finished the conflict owing the United States an astronomic sum, the greater part of which was never paid. It is true that the amount lent by Britain to Allies and Dominions equalled roughly the total borrowed, but the result of borrowing in the last war suggests that credit on the same scale could not be repeated under the existing conditions.

That this fact is realised by the authorities is evident from the prompt steps taken to check-up on all privately held foreign investments, and to force the sale to the Government of all holdings of foreign exchange and gold. Purchases abroad, and particularly from the Western Hemisphere, are evidently to be restricted as far as possible to war essentials, and from this viewpoint motor spirit rationing may be a necessary measure.

But Britain cannot get it both ways. By limiting motor spirit consumption so severely, the authorities are not only putting the public to serious inconvenience through curtailment of public services and private motoring, but impeding commercial motoring which is intimately connected with the export trade by means of which the war must be largely financed. These are facts—without questioning whether the policy is right or wrong!

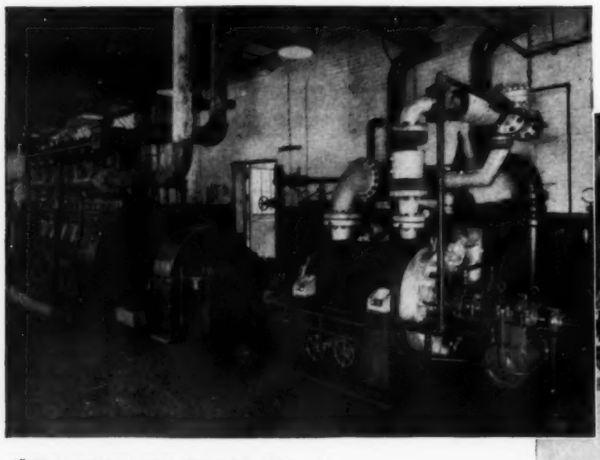
Smaller sales of private and commercial motor spirit also mean a heavy cut in State revenue, as any increased consumption by Government vehicles, air force and mechanised army units will not produce fuel or vehicle tax revenue. Government receipts from taxation of motoring and transport were estimated to produce nearly £98,000,000 in the current financial year. A large part of this expected revenue must now go by the board, and since Government expenditure has increased enormously it must be replaced by other taxation.

Loss of car tax and motor spirit duty does not nearly exhaust the catalogue of prospective tax and other allied losses. Reductions of receipts from income tax on oil and motor manufacturing earnings, also from curtailed bus services, resulting from rationing, must be taken into account. Such losses will only be made good to the extent that the Government itself spends money on petroleum supplies from oil companies and war material from former motor manufacturing concerns.

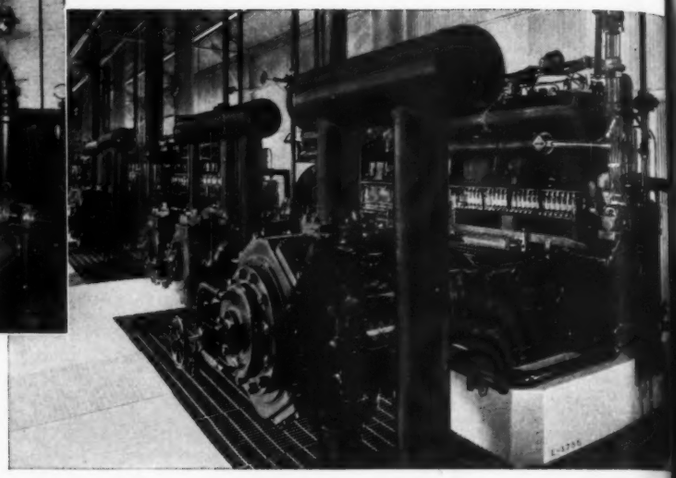
Heavy losses through interference with export business and reduced revenue, as well as impediments to general trade activity, have thus to be set against the exchange benefit resulting from motor spirit rationing.

Decisions as to where the ultimate advantage lies must rest with the Government; but the adverse factors are so heavy as to suggest that rationing on its present drastic scale may offset in other ways all the advantages gained.

FOR THE PETROLEUM I

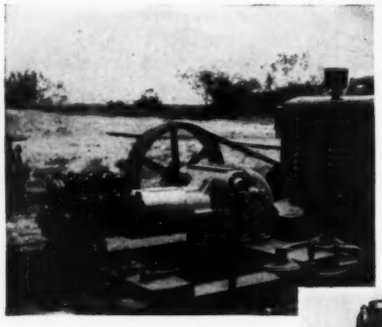


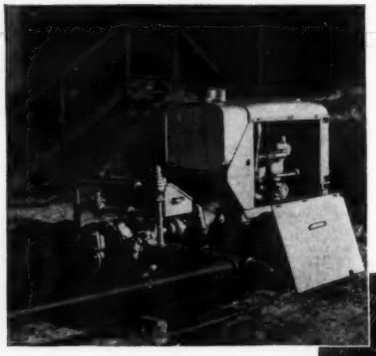
4" 7-stage Worthington Forged Steel Barrel Centrifugal Hot Charge Pump, driven by Worthington 375-hp. Gas Engine, through speed increasing gears



Part of a group of five Worthington Angle Gas Engine Gas Compressors in natural gas repressuring service

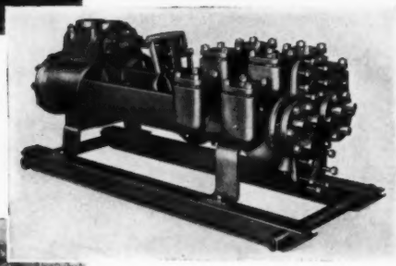
Below — Worthington Enclosed Crankcase Power Pump, driven by gas-gasoline engine with Worthington Multi-V-Drive, in oil gathering service



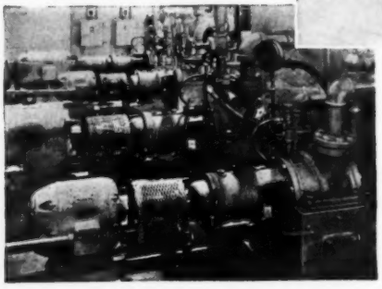


Left—Worthington Rotary Pump, gas-gasoline-engine-driven, in gathering service in the oil fields

Two Worthington 240-hp. Gas Engines connected through gears to Worthington Centrifugal Pipe Line Pumps



Right—Worthington High-Pressure Duplex Steam Pump for boiler feed service



A group of four Worthington Type H Centrifugal Refinery Pumps

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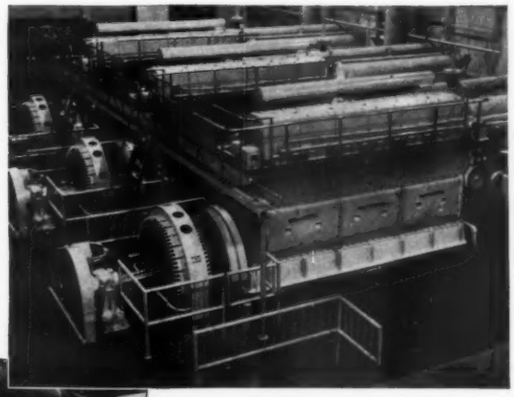
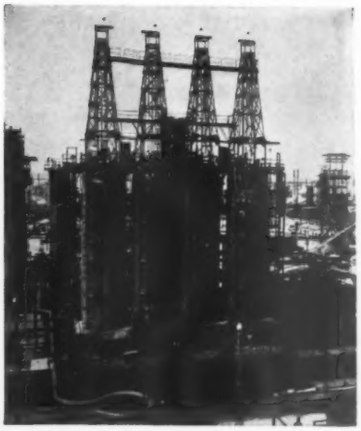
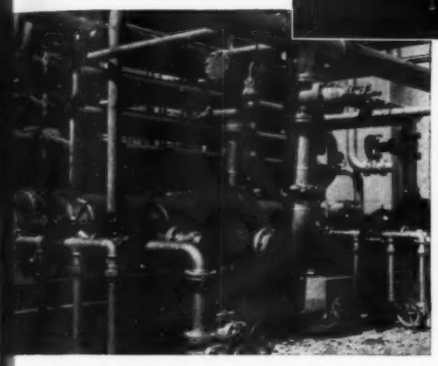
INDUSTRY . . .



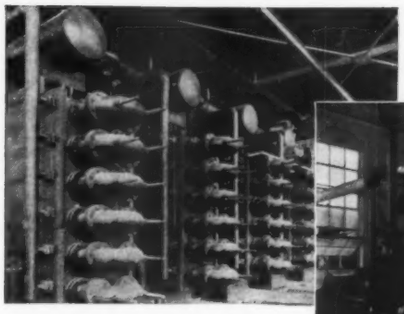
Right—Three of four Worthington Convertible Gas-Diesel Generating Units, in the service of a leading petroleum producer



Complete hydraulic decoking and coke transportation systems for economical removal and transportation of coke from coke chambers in oil refineries



Two Worthington Centrifugal Pumping Units . . . three pumps in line . . . each driven by Moore Turbine operating on natural gas, for rich oil, lean oil and reflux service



Above—Worthington-Carbondale Chilling Machines, for ammonia direct-expansion operation, in a solvent dewaxing plant

Below—Worthington-Carbondale Horizontal 2-stage Ammonia Compressors, motor-driven, dewaxing oil in a refinery

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New COLOMBIAN PIPE LINE Brings Barco Oil To Sea

Connecting Link Across Andes to Tidewater Adds Important Source to World Supply—Airplanes Employed To Transport Materials Used in Building Line.

ON OCTOBER 15 oil produced in the Petrolea field on the eastern borderline of Colombia began flowing through the newly completed pipeline of South American Gulf Oil Company to Coveñas on the shore of the Caribbean. Two weeks later a Socony-Vacuum tanker sailed from the port with the first cargo of this oil to enter the international market.

Behind this simple statement lies one of the petroleum industry's epic stories of achievement in the subjugation of the jungle, the overcoming of almost insuperable obstacles to transportation, the development of the field and the building of the pipeline itself across a formidable spur of the Andes. The arrival of oil at tidewater marked the fruition of thirty-five years of effort and the proceeds of this first cargo will bring the initial return on an investment which already exceeds $40,000,000.

The Barco concession as it is commonly known, which includes Petrolea and neighboring fields, underwent many vicissitudes before its oil began to travel over the mountains and down to the sea. It was originally granted in 1905 to General Don Vergilio Barco who had discovered seepages that suggested the probability of large deposits in the area. For several years General Barco tried unsuccessfully to enlist capital in the development of the concession.

In 1918 the concession was transferred to Compania Colombiana de Petroleo. Three-quarters of the company's shares were owned by Henry L. Doherty & Company, and one quarter by the Carib Syndicate. In 1925 the Doherty interest was taken over by South American Gulf Oil Co., a wholly owned subsidiary of Gulf Oil Corporation. The following year the concession was cancelled by the Colombian government on the claim that the required amount of development work had not been performed. Attempts to obtain its reinstatement resulted, in 1931, in an undertaking known as the Chaux-Folsom agreement which was ratified by the Colombian Congress. It granted to the Colombian Petroleum Company a contract for exploration and development of the Barco concession and to the South American Gulf Oil Company authority to construct a pipeline to tidewater with the specific provision that the line must extend wholly through Colombian territory. During the next few years much preliminary work was done and several wells were drilled. Then, in 1936, the entire holdings of the Gulf Company were purchased by The Texas Corporation and Socony-Vacuum Oil Co., Inc. Later they acquired the interest of the Carib Syndicate. Except for a few shares the Colombian Petroleum Company, capitalized at $10,000,000, is owned in equal parts by Texas and Socony while the South American Gulf Oil Company is wholly owned on the same basis.

The present concession which runs for fifty years from August 24, 1931 covers approximately 400,000 hectares (988,000 acres) lying between the Perija mountains and the Colombia-Venezuela boundary line in the upper Catatumbo basin. Under the terms of the contract the concession holders were required to select by 1936 at least 50,000 hectares in blocks of 10,000 hectares each and by 1941 additional blocks sufficient to bring this total to 200,000 hectares. The remainder of the concession, except for necessary rights of way, will then revert to the government.

Other provisions stipulated that within three years after production reached 3,000 metric tons per day a pipeline should be laid and that when it arrived at 4,000 metric tons daily a refinery should be built on the concession. In accordance with these requirements the pipeline has been built and construction of a refinery of 500 bbl. daily has been started at Petrolea.

Three fields have been located on the Barco concession. Of these the one most fully developed is the Petrolea field on which sixty producing wells have been drilled. Further north is the Rio de Oro field which now has seven producers, while on the south, on what is known as the South Petrolea dome a single well has found production at Carbonera. Besides these sixty-eight producing wells thirteen dry holes have been drilled since the start of development.

Geologically the area is described as a broad synclinal basin lying between the Perija mountains on the west and the subsidiary Petrolea range on the east. The basin deepens toward the northward. The Petrolea uplift on the eastern side where most of the present producing wells are located is structurally a mountain range truncated to low hills by erosion. On this same uplift are located, further north, the Tarra and Los Manuelos fields in Venezuela.

The Rio de Oro field is located in the foothills of the Perija mountains on the west side of the concession. The structure is a narrow, tight anticline, considerably faulted. It produces 38° API gravity oil from sands in the Catatumbo formation of Eocene to uppermost Cretaceous age.

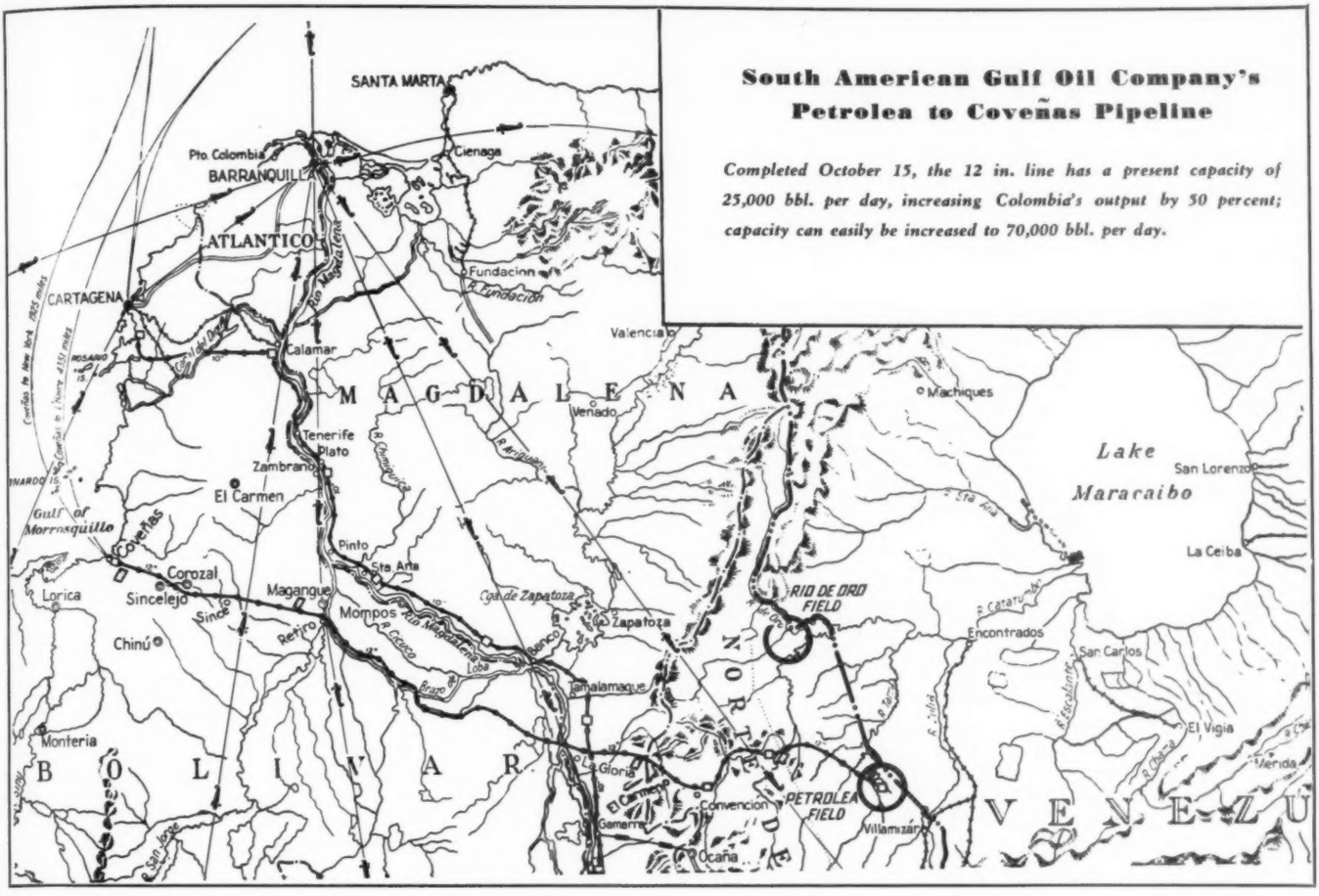
While the fields contained within the concession have not been fully defined production already is more than sufficient to fill the present capacity of the pipeline and enough has been learned to prove that the area justifies the large expenditure that has been made on it.

At the present time the company has five light Diesel-driven rotary rigs, two heavy Diesel rigs and one steam-powered rotary rig at work in the Petrolea field. One rig is operating at Rio de Oro. A second well is drilling at Carbonera and one additional wildcat well is rigging up.

Development work in these fields presented many difficulties since the whole area was virgin jungle which had to be cleared away for roads, camps and drilling sites. The thousands of tons of machinery and supplies required for the operations were brought in by way of Lake Maracaibo and moved up the Catatumbo on barges. Material for Petrolea went up the Tarra and Sardinata rivers to Puerto Reyes or by railroad to Puerto Leon and thence by road to Petrolea. Equipment for Rio de Oro was moved up the river of that name to the camp. From the Colombian side a road was built connecting the camp with Cucuta. Airplanes were relied upon largely for communication and the movement of personnel. Airports have been built at both Petrolea and Rio de Oro. Within the concession itself a light railway and several kilometers of surfaced highway connect important points.

Preparations for building of the pipeline have been under way for the past three years. Following extensive surveys the route was decided upon and construction authorized in 1937. Actual work on the line was begun in February 1938. Because of the requirement that the line must lie wholly within Colombian territory it was necessary to carry it over one of the Andean ranges and the whole eastern section of the route traversed jungle territory without towns, roads or transport facilities. A large part of the cost of the line has been incurred in building a modern highway which parallels the pipe throughout the eastern portion of its course.

To meet the immediate problem of transporting the pipeline material, however, the airplane was called into play and the Barco pipeline has the distinction of being the first ever constructed in which a great part of the equipment was conveyed by air. Ten freight planes were employed and moved a total of 11,000,000 lbs. of materials. Suspension bridges 350 ft. in length and weighing 176,000 lbs. each were especially designed to be transported by plane. For one bridge alone 240 separate trips were made, carrying 8,000 bags of cement, bridge steel, concrete mixers and other machinery. The total distance flown in the course of construction work was over



South American Gulf Oil Company's Petrolea to Coveñas Pipeline

Completed October 15, the 12 in. line has a present capacity of 25,000 bbl. per day, increasing Colombia's output by 50 percent; capacity can easily be increased to 70,000 bbl. per day.

1,000,000 kilometers. In all these difficult operations only one plane and two aviators were lost.

The general direction of the pipeline is east to west, from Petrolea to Coveñas on the Caribbean, a distance of 252 miles. The line has a present capacity of 25,000 bbl. daily but this can be increased to 70,000 bbl. by loops and the installation of additional pump stations.

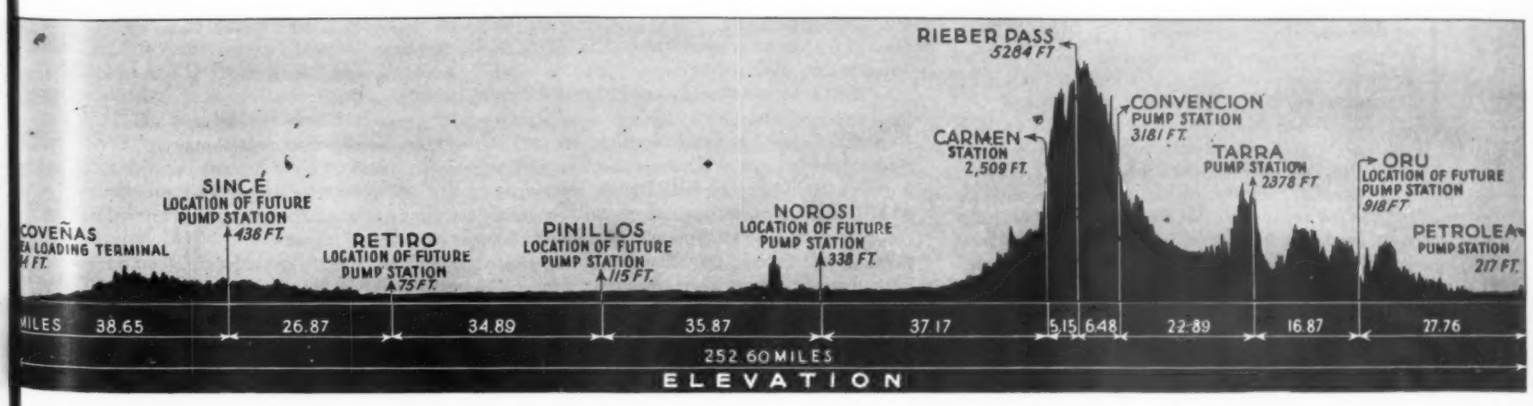
Leaving the tank farm at Petrolea the line runs 46 kilometers in a northwesterly direction to Estacion de Oru at an elevation of 918 ft. At a further distance of 28 kilometers is Estacion de Convencion at an elevation of 3,482 ft. From here the line climbs to its highest point, 5,286 ft. or just over a mile, traverses Rieber Pass, named for the chairman of The Texas Corporation, and goes on to Estacion del Carmen at an elevation of 2,510 ft. It then drops down to the western foot of the range and follows a relatively level course northwesterly to the Magdalena River proceeding thence in a westerly direction to the terminus at Coveñas.

Three pumping stations are now in operation on the line. One of these is at Petrolea, a second at Tarra near the point where the line crosses the Tarra river, and the third at Convencion near the crest of the range just east of Rieber Pass. For the remainder of its course the oil is carried by gravity. Sites for additional pump stations have been located at Oru, 46 kilometers from Petrolea, Norosi, 194 kilometers distant, Pinillos, 254 kilometers, Retiro, 312 kilometers, and Sincé, which is some 64 kilometers east of Coveñas.

Each pumping station is equipped with two 750 h.p. Diesel engines and centrifugal pumps capable of handling 25,000 bbl. daily, at a pressure of 900 lbs. per sq. in.

The importance of the Barco development and the new pipeline to Colombia is indicated by the fact that the 9,125,000 bbl. which the line is expected to handle annually will add roundly 50 percent to the yearly shipments of oil from the country which in 1938 amounted to 18,535,000 bbl. Under the terms of the concession the Colombian government is to receive a royalty of 10 percent in the field or 6 percent at the terminal port, a substantial addition to its revenues. The whole project stands as a noteworthy industrial achievement involving a vast capital investment and accomplished only by bold enterprise and high engineering ability.

Most striking feature of the new line is the abrupt change in elevation, shown below, from practically sea-level to 5,000 ft. and back to sea-level all within 98 miles.



PARTITION Of Poland's Oil Industry

By David E. Morgenstern

THE POLISH oil fields are among the oldest in the world. Once a major factor in the international industry, they have shown a steady decline since 1909, accounting for only 0.19 percent of the entire world output in 1938, thus occupying 18th place among the producing nations. The former Polish government fully realized the importance of the petroleum industry and undertook a long range project which would have cost $13,000,000 in an effort to modernize the industry and thus increase economical production. The money was to have been spent on drilling and exploration, using new rotary outfits, geophysical prospecting, and geological surveys. The recent war disrupted these plans. It may be thought that since oil is so valuable for both Russia and Germany both countries will considerably increase the production of those fields they took over, in order to satisfy war needs. It is well known, however, that any considerable expansion of this sort takes a long time to perfect.

It is unquestionably true that the Polish sub-carpathian region has very favorable geological conditions for a considerable increase in oil production. Great quantities of oil are still present in the ground. Before they can be brought to the surface, however, it will be necessary to make a large investment for new drilling, new equipment, and for a wide application of water, gas, and air flooding, techniques as yet practically unknown in Polish oil fields. Practically all of the existing fields have suitable geological conditions for the application of water, gas, and air flooding. The outstanding Polish exponent of this method, the Schodnica oil field, had increased its production by 50 to 250 percent in the case of individual wells between 1931 and 1938.

An increase in the oil output of Poland is nothing but a question of tremendous investment in time and money. The present political and economical situation of both Germany and Russia are far from ideal to allow for such investments. The chances are, therefore, that the Polish oil fields will decline, rather than advance, at least so long as the war is in progress. An identical set of facts faced the industry during the first World War, and many of these conclusions are drawn from the results of that period.

DAVID E. MORGENSTERN was born in 1913 in Kryg (Gorlice), in the heart of the western oil fields of Poland. Descended from a family which has been connected with Polish oil production since the inception of that industry, it was only natural that he devoted himself to a serious study of petroleum technology. After graduating from the Gimnazjum in Gorlice, Mr. Morgenstern spent two years in the oil fields as a supervisor with Morgenstern & Ska Oil Co., followed by refinery work with the Malopolska Refinery.

For several months after leaving the refinery Mr. Morgenstern toured Europe, making a thorough investigation of oil fields throughout the continent. He then enrolled in L'Université de l'Etat de Liége, in Belgium, for the excellent course in Mining Engineering. Desiring further specialization in the petroleum industry he next came to the United States in the spring of 1938, entering shortly thereafter the Massachusetts Institute of Technology, in Cambridge, Massachusetts. He was graduated from there with the degree of Bachelor of Science in Petroleum Production. Much of the data contained in this article was first obtained for Mr. Morgenstern's bachelor thesis at MIT.

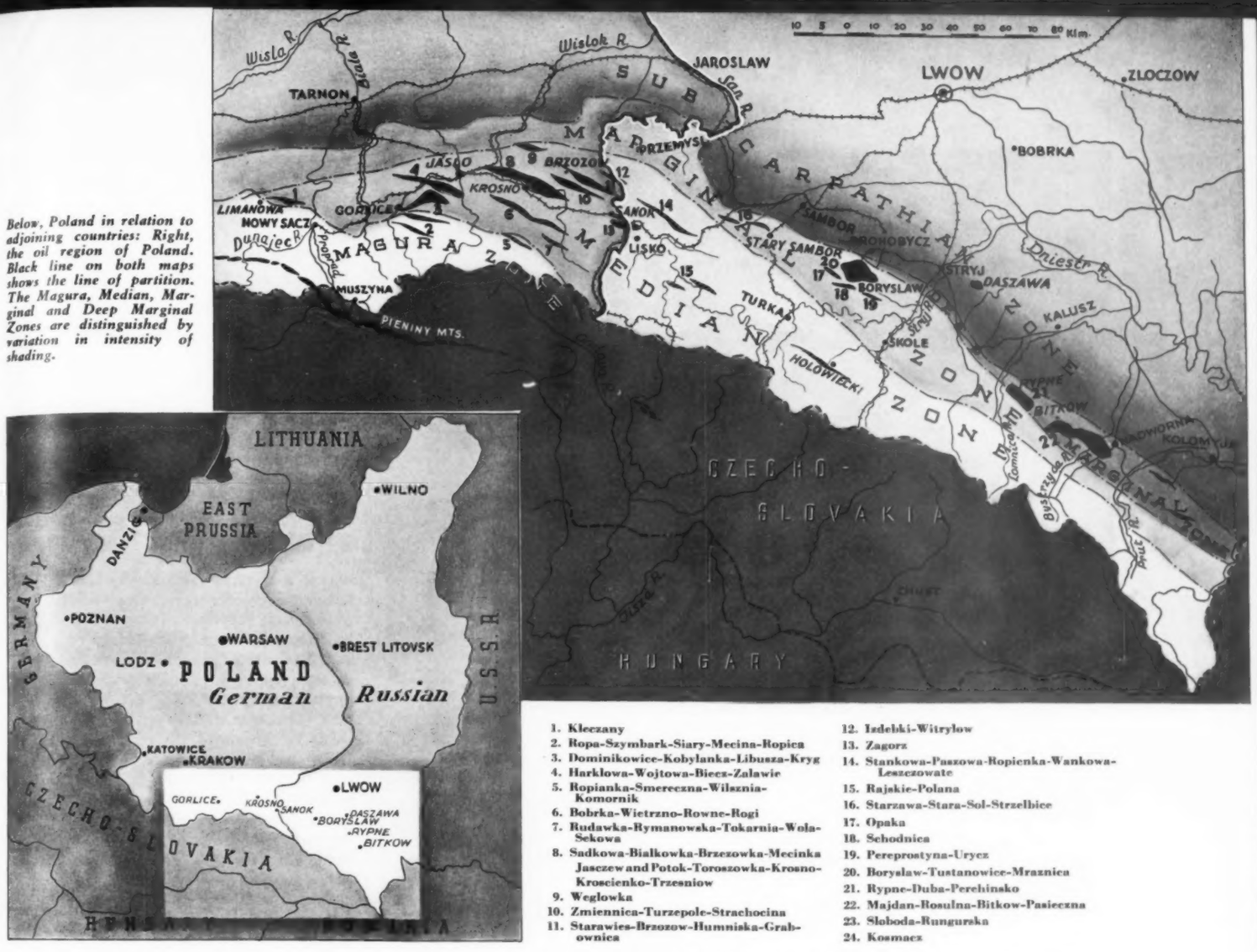
At the present time Mr. Morgenstern is enrolled in the graduate school of Columbia University, where he is specializing in the geology of oil production.

POLAND, until eight weeks ago the greatest power in eastern Europe, ceased to exist as an independent country as a result of the war between her and two powers; Russia on the East, Germany on the West.

The area of independent Poland was 149,958 sq. miles with a population close to 34,000,000 or about 256 inhabitants per square mile. The partition line of Poland between Russia and Germany runs from North to South along the following rivers: Pissa, Bug, and San. The part lying on the West of this line went to Germany. This amounts to almost 60 percent of the total area with a population of about 21,000,000 or 63 percent of the population of independent Poland. Germany took domination of a population which was ethnographically speaking practically 100 percent Polish. This area was always the most developed and the most progressive part of Poland containing 80 percent of Polish industry and the best agricultural country. Here also are the largest cities, such as Warsaw, with a population of 1,261,000; Lodz (665,000), Poznan (269,000), Krakow (255,000), and Katowice (133,000). Krakow is considered the capital of the entire mining district of Poland.

Russia conquered the remaining area of Poland which amounts to 40 percent or about 60,000 square miles. This area is for the most part lowland and contains the great swamps of Polesie. The most important and practically the only large industry situated here is the petroleum industry with its capital Lwow possessing a population of 318,000. Most of this area is used for agriculture. The best land is in the Podole section. The population which fell under Russian domination is about 80 percent Ukrainian and White Russian. These peoples have always been very poor, accustomed to a low standard of living. There are among them men who have never seen a train or a car in their lives and men who have never tasted sugar.

Of the 20,118 km. of the standard gauge railway lines, close to 62 percent will belong to Germany, while only 8,160 km. are situ-



Below, Poland in relation to adjoining countries: Right, the oil region of Poland. Black line on both maps shows the line of partition. The Magura, Median, Marginal and Deep Marginal Zones are distinguished by variation in intensity of shading.

1. Kleczany
2. Ropa-Szymbark-Siary-Mecina-Ropica
3. Dominikowice-Kobylanka-Libusza-Kryg
4. Harklowa-Wojtowa-Biecz-Zalawie
5. Ropianka-Smereczna-Wilszna-Komornik
6. Bobrka-Wietrzno-Rowne-Rogi
7. Rudawka-Rymanowska-Tokarnia-Wola-Sekowa
8. Sadkowa-Bialkowka-Brzezowka-Mecinka Jasczew and Potok-Toroszowka-Krosno-Kroscienko-Trzesniow
9. Weglowka
10. Zmiennica-Turzepole-Strachocina
11. Starawies-Brzozow-Humniska-Grabownica
12. Izdebki-Witrylow
13. Zagorz
14. Stankowa-Paszowa-Ropienka-Wankowa-Leszczowate
15. Rajskie-Polana
16. Starzawa-Stara-Sol-Strzelbice
17. Opaka
18. Schodnica
19. Pereprostyna-Urycz
20. Boryslaw-Tustanowice-Mraznica
21. Rypne-Duba-Perehinsko
22. Majdan-Rosulna-Bitkow-Pasieczna
23. Sloboda-Rungurska
24. Kosmacz

ated in the newly acquired Russian territory. The 60,700 km. of roads are, in general, in very bad condition and will be divided as follows: 22,000 km. will become Russian, and about 38,000 km. will go to Germany. However, the Polish railway system was one of Poland's greatest advantages, there being 52 km. of track per thousand square kilometers against only 44 km. of track per thousand square kilometers in the United States.

OIL PRODUCTION

The total oil production of Poland in 1938 was 3,801,000 bbl., which amounted to about 0.19 percent of the world output. Some 35 percent of this production came from the territory west of the San River (now Germany). The total number of refineries is 37, with a total capacity of 8,700,000 bbl. of oil per year. These are distributed as follows: 14 refineries with a total capacity of approximately 2,500,000 bbl. of oil with two cracking plants, at Glinik-Marjampolski (Gorlice) and Czechowice. The remaining 23 refineries, with a total capacity of about 6,200,000 bbl., are east of the San River with only one cracking plant.

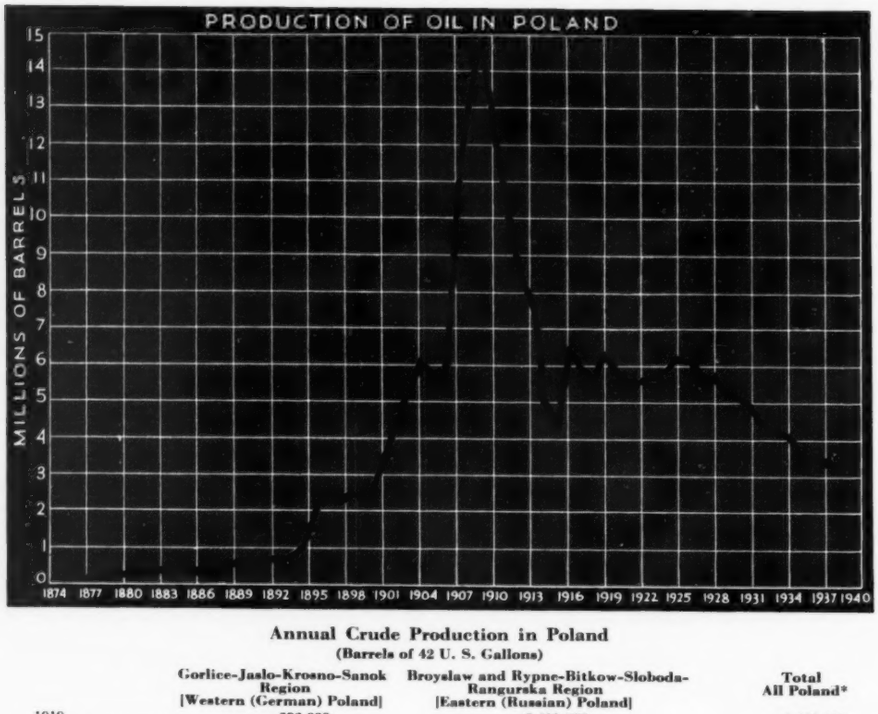
Now let us see what importance the newly acquired oil fields will have for Germany and Russia for both of whom oil production is of the greatest economic importance. The 1938 statistics for Poland show only a 10 percent surplus of production over consumption. Germany incorporated that part of Poland which couples about 80 percent of total Polish industry with about 80 percent of total consumption of petroleum products. Now the same area has only about 35 percent of the Polish production, which amounts to 920,000 bbl. annually. Therefore this area will have to import about 2,100,000 bbl. of oil per year. Thus, we see that the newly acquired territory will, so far as the oil situation is concerned, become a liability rather than an asset. The consumption of oil in Germany in 1938 was almost 600,000,000 bbl. Therefore, the gain in production is too small to be of any importance to it.

Russia received the most important wells of Boryslaw, Rypne, Bitkow, Schodnica, and Urycz. With 65 percent of total Polish oil production, it gains about 2,200,000 bbl. of oil per year. This, however, amounts to only about four days of total Russian oil production. The cost of production of oil in Russia is much lower than in Poland and because of transportation difficulties it is to be expected that the surplus of production over consumption will be exported to German territories of former Poland, Danzig and Czecho-Slavakia, since these were always the consumers of this oil.

REFINING

The refining industry of Poland was situated mainly in the producing area. Of the 37 operating refineries, 13 of the biggest have a total capacity of 7,524,000 bbl., which amounts to 91 percent of the total refining capacity of the country. The four largest refineries are situated at Czechowice, Trzebinia, Dziedzice, and Lwow, all comparatively far from the producing centers. The next largest refineries are situated in the newly acquired German territory, Glinik-Marjampolski, Libusza (now out of operation), Jaslo, Jedlicze, Krosno and Usztrzyki. The remaining four large refineries are situated in Drohobycz and, together with the large Lwow refineries, constitute an important refining center which will become part of the Soviet. The Polish refineries are usually of the oldest types and some are examples of the first types of refineries ever built, as in Kleczany and Gorlice.

There are only three new cracking plants, in Drohobycz (Galicja Oil Co.), in Glinik-Marjampolski (Malopolska Oil Co.), and in Czechowice (Vacuum Oil Co.). The largest company in the refining industry (as well as



Annual Crude Production in Poland
(Barrels of 42 U. S. Gallons)

	Gorlice-Jaslo-Krosno-Sanok Region [Western (German) Poland]	Broyslaw and Rypne-Bitkow-Sloboda-Rangurska Region [Eastern (Russian) Poland]	Total All Poland*
1919	392,000	5,431,000	6,461,000
1920	374,000	4,933,000	5,801,000
1921	385,000	4,443,000	5,347,000
1922	425,000	4,378,000	5,415,000
1923	427,000	4,583,000	5,592,000
1924	434,000	4,821,000	5,879,000
1925	495,000	5,066,000	6,160,000
1926	532,000	4,868,000	6,034,000
1927	551,000	4,302,000	5,478,000
1928	579,000	4,439,000	5,476,000
1929	549,000	3,940,000	5,618,000
1930	649,000	3,576,000	5,115,000
1931	741,000	3,325,000	4,813,000
1932	726,000	2,813,000	4,220,000
1933	731,000	2,721,000	4,174,000
1934	724,000	2,560,000	4,011,000
1935	752,000	2,437,000	3,902,000
1936	817,000	2,439,000	3,870,000
1937	879,000	2,315,000	3,799,000
1938	1,061,000	2,208,000	3,828,000

*Includes production in other fields data for which does not appear in columns under Eastern or Western fields.

among the producers) is the Malopolska Oil Co., owning the six largest refineries and refining nearly 45 percent of the total crude oil output. Four of these refineries are working at 80 percent capacity. Other important refining companies are P. F. O. M. Polmin and Galicja Oil Co. These companies represent 75 percent of the refining industry in Poland.

EXPORT

Transportation facilities for crude oil going into Germany are rather good as that part of the oil industry taken by Germany is mostly situated near railroad stations and the two big refineries, Czechowice and Dziedzice, are practically on the former Polish-German border. Other refineries and oil fields are situated within a radius of 100 to 150 miles from the former German border. The southwestern part of former Poland, being more highly industrialized than the rest of the country has comparatively good transportation facilities, the main railroad centers being at Tarnow, Krakow and Katowice.

The problem of transportation facilities into Russia from the refining and production centers acquired by that country presents a different aspect. Eastern Poland has always had the worst transportation, railroads, and roads of the entire country. This problem was of major importance in former Poland and now that the important railroad centers east of San River at Przemysl and Lwow have been destroyed, the question of transportation in this section will present a real problem for Russia. However, it is likely that Eastern Polish petroleum will be consumed within the boundaries of former Poland. In the remote eventuality that these products should be transported to Russia, costs will increase rapidly, due, not only to the immense distances, but mainly to the fact that Russian railways are not of standard gauge and the oil and its products from Polish tank cars would have to be unloaded and reloaded on Russian tank cars at the former border.

DRILLING PRACTICE

Drilling practice in the Polish oil fields is not at all progressive. The Canadian system of drilling, already forgotten in most oil fields in the rest of the world, still plays an important part in this region. In 1938 41 percent of the total footage drilled was by means of the Canadian system. In this system the derrick is usually constructed of pine wood. The height of such a derrick varies from 50 to 60 ft., the floor space being about 17 sq. ft. The walking beam is about 12 by 12, 9 by 13, or 10 by 14 in. In raising the tools steel rods of one inch or ⅞ in. diameter are used. A locomotive type boiler at least 100 ft. away from the rig supplies the power. The steam is conducted through two inch pipes insulated with clay and tar paper to prevent heat losses. Steam engines are usually horizontal, have one or two cylinders and are of 60-65 h. p. The bits differ greatly from those used in other fields, one of the most characteristic being the "eccentric bit", which due to its eccentricity, drills a larger hole than it would as a result of its actual size, saving the use of underreamers. Another common type is the "straight bit" which is similar to the California Pattern type. These bits are usually six to ten feet in length. All tools are connected in order: rods (joint), jars, stem and bit. After each blow, the tools are turned through an angle of 30 to 40 degrees by an assistant driller who is constantly walking around the bore-hole. A guide consisting of four wings, radiating from a common center inserted into the string of tools, is often used, as it is of great service in drilling in the disturbed and often steeply inclined strata met in the Carpathian region since it helps to keep the hole vertical. This system of drilling is used for wells not exceeding 2,000 ft. in depth. Under normal conditions the drilling of a well 1,000 ft. deep requires about six weeks' time.

The cable tool method of drilling, known as the "Pennsylvanian System" was not introduced on a large scale until 1922. At present

Polish Production of Petroleum Products
(Tons)

Year	Gasoline from Natural Gas	Gasoline from Crude Oil	Kerosene	Fuel Oil	Lubricating Oil	Paraffin
1920	653	84,810	186,875	100,650	98,951	2,732
1921	728	67,983	178,450	112,352	104,980	24,680
1922	1,083	87,931	225,500	133,150	120,749	39,045
1923	2,285	91,349	219,879	104,095	100,650	29,824
1924	3,783	109,650	217,197	124,658	131,295	37,499
1925	10,219	103,550	223,100	128,400	141,250	37,410
1926	19,860	107,200	257,190	170,680	113,655	43,635
1927	30,590	99,400	224,000	127,230	106,200	40,000
1928	35,100	103,000	238,500	143,950	119,200	44,210
1929	38,000	111,850	207,180	134,650	101,100	39,399
1930	42,410	133,400	190,250	116,200	99,919	36,385
1931	45,100	112,400	193,190	127,385	94,210	34,770
1932	42,800	109,999	176,500	116,000	81,200	33,200
1933	46,400	99,900	191,900	111,600	88,420	32,210
1934	44,887	93,250	189,000	90,700	95,000	31,200
1935	41,600	94,200	162,190	103,350	79,200	27,660
1936	42,300	96,800	160,380	102,050	58,620	27,600
1937	43,000	99,645	159,000	112,400	50,200	26,035
1938	47,316	110,226	155,461	99,856	51,907	24,849

53 percent of the total footage was drilled with the cable tool system. Few changes were made from the standard cable tool method to meet the Polish geological conditions. Power used for the cable tool system is the same as in the Canadian system and all equipment is practically the same as the standard cable tool system used in other fields. Actual drilling time with cable tools is about 45 to 55 percent while in the Canadian system actual drilling time is only about 20 percent. With this method it is possible to drill a well to 1,800 ft. in 30 days including casing. The average time for drilling a well of 1,000 ft. is about thirty days.

At the present time there are only five rotary rigs in common use. They are responsible for only 5.8 percent of the total footage drilled in Poland in 1938. Due to the very irregular, hard and caving formations the application of the rotary system does not give the results obtained in other oil fields of the world. The time necessary to complete a well in Poland is very long. With cable tool drilling it takes usually five weeks to complete a well to 1,500 ft. The use of rotary drilling reduces the time necessary to complete a well, but the time saving is not in proportion to the cost of the outfit and operating costs. The largest saving obtained by the use of the rotary drilling is in casing, because in Polish oil fields one foot of hole drilled with the Canadian or Cable Tool method requires over 61 lbs. of casing, which is much greater than is necessary in other oil fields.

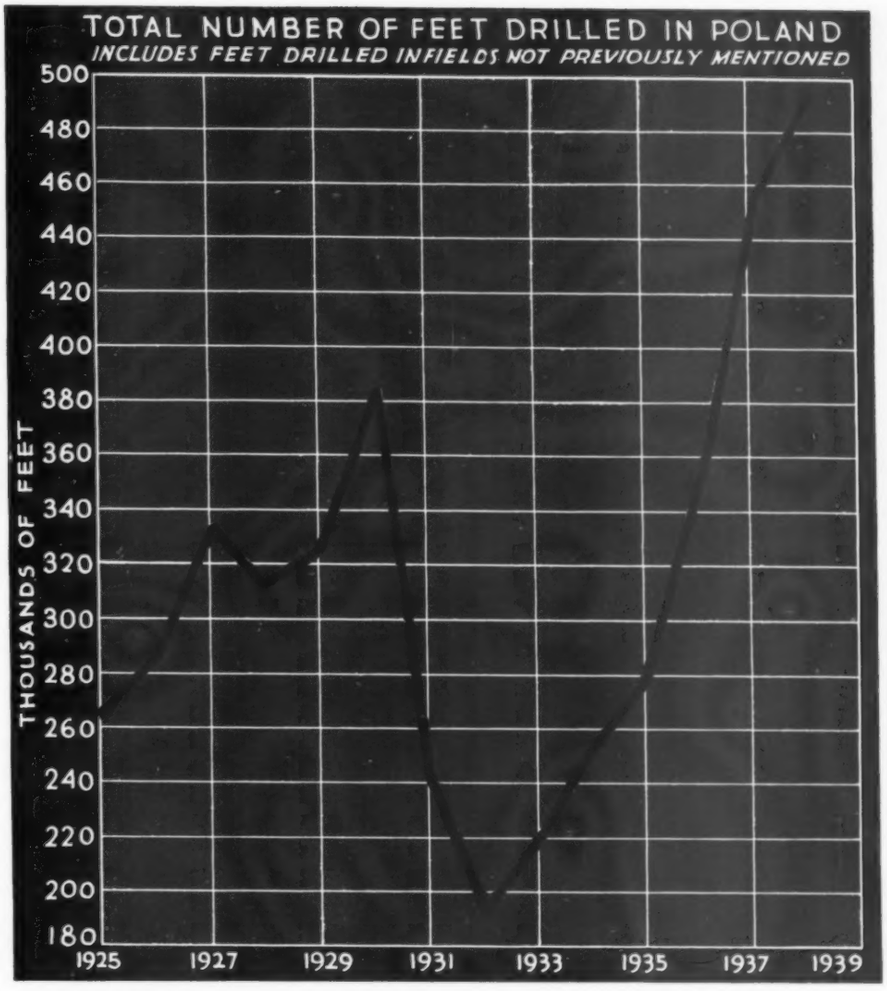
PRODUCTION PRACTICE

The production of oil in the former Polish oil fields differs from the standard methods of production used in the United States. Among the 3,740 oil-producing wells there are only 20 flowing wells, 903 bailing and swabbing wells, the remaining 2,690 wells being pumped. Air-lift and water-flooding methods are unknown with the exception of a few isolated cases. In only five fields was air-flooding applied, in all cases giving an increase of 50-200 percent in production, but in four cases it was stopped after two to four years of application because of mechanical difficulties and economic considerations.

Bailing has proved more practical than pumping in many cases. Pumps will not withstand the cutting effect of sand-laden oil, but the large diameter of Polish wells render bailing feasible. The loose sands of Texas, Louisiana and California produce the same conditions, but bailing there would be uneconomical because of the great depth and small diameter of the wells.

Swabbing is used mostly in the eastern fields of Boryslaw, Rypne, and Bitkow regions, where the pressure is insufficient for flowing production but the wells are too big to be pumped. The swab is either of single or double rubber, is usually lowered on a wire drilling cable, and may produce as much as 2,000 bbl. per day. Steam power is usually used for bailing and swabbing. The steam drilling engines are left at the well after its completion in case it has to be bailed or swabbed. The engines are usually single or double cylinder, horizontal engines of about 45 h.p.

Pumping is done in the same way as in any other oil field. Pumps are usually two inches in diameter, although a three inch pump can occasionally be seen. Sucker rods of 9/16 in. or 5/8 in. or in the deeper wells 3/4 in. rods are used. Common sources of power are gas, gasoline, or crude oil engines. Very few wells have unit pumping outfits. Usually wells are pumped by means of a central-multiple power One central power will pump about 15-20 wells. The transmission lines from the central power to individual wells are made out of old drilling cables or rods of different diameters, depending on the depth of the well and on its location. Pumping jacks are of different designs, the most common being similar to the



Drilling Activity in 1928 - 1938

	Number of Wells Drilled			Number of Feet Drilled			Number of Active Wells		
	Western Poland (German)	Eastern Poland (Russian)	Total* Poland	Western Poland (German)	Eastern Poland (Russian)	Total* Poland	Western Poland (German)	Eastern Poland (Russian)	Total* Poland
1928	55	96	177	93,850	154,600	312,500	894	880	2624
1929	61	70	156	111,500	153,600	324,000	955	879	2754
1930	47	53	142	126,400	157,150	384,100	1016	897	2909
1931	41	45	106	94,300	82,700	244,500	1085	892	2976
1932	41	34	96	83,000	50,850	193,000	1119	891	3036
1933	47	28	99	106,100	49,500	219,500	1117	902	3126
1934	55	36	113	127,500	61,250	255,800	1265	951	3302
1935	70	40	138	129,800	77,600	279,800	1318	975	3397
1936	85	33	148	157,900	94,400	354,500	1382	1130	3557
1937	86	56	173	219,500	125,710	457,500	1513	1240	3815
1938	100	52	194	255,800	124,590	496,400	1684	1269	4097

*Includes drilling in other fields, data for which does not appear in columns under Eastern or Western Poland.

Principal Polish Oil Companies
(Producing 70 Percent of Polish Crude)

Name	1938 Drilling (Feet)	1938 Production (Barrels)
Malopolska Oil Co.	115,000	1,440,000
Galicja Oil Co.	22,850	251,000
Limanowa Oil Co.	1,610	216,000
Gazy Ziemne Oil Co.	26,200	196,000
Morgenstern & Co. Oil Co.	36,900	138,000
Vacuum Oil Company	7,140	104,000
Petronafta Oil Co.	7,680	75,500
Polmin Pollon Oil Co.	38,600	70,400
Uryeka Ska Oil Co.	4,000	51,500
Dorreger B. Oil Co.	15,000	50,000
Lockspeiser Oil Co.	.....	46,500

Jones and Hammond type. Oil is usually pumped or bailed to individual small tanks, then repumped (often by hand pumps) to a central gathering tank and then by pipeline or horse drawn wagons to the nearest railroad stations. Practically every well produces a certain amount of gas. If the amount of gas is insufficient for commercial use, or for the manufacture of natural gasoline, the gas escapes to the air or it is used for boiler fuel.

COSTS

Since drilling is always undertaken by the oil company itself, the cost of drilling varies greatly, depending upon location, depth, condition of drilling, and efficiency of management. There are no drilling contractors in Poland. Included in the cost of drilling are: actual drilling operations; cost of equipment and depreciation, casing, power costs, overhead and transportation.

The average cost of drilling, including all of these items is $10.73 per foot. This figure is based on investigation of private companies. As already mentioned, formations are very complicated and not known in advance. This increases the cost of drilling as each oil or gas indication is tested for at least twenty-four hours. Each water horizon has to be shut off with a new string of casing so that a 1,500 ft. well may have a 9, 7, 6, 5, and 4 in. casing program. Labor cost is comparatively low, as the union wage for a driller is $1.28 for an eight hour day's work and the average pay for oilfield workers is 87 cents per eight-hour day.

Production costs include: cost of lease and drilling, pumping, cleaning, deepening, storage, labor, cost of all equipment, power, gathering lines, transportation to railroad or pipeline terminal and overhead. Taking into account all the foregoing items, the cost of production varies extensively with an average cost of $2.50 per barrel.

PRODUCING FIELDS

The Polish producing areas can be divided into four separate zones. The expression "zone" is used here to define the facies region as this word is widely used in the literature concerning that subject, and by all Polish geologists. The zones are:

I. **Magura Zone. (German-Poland)**
II. **Median Zone. (German-Poland)**
III. **Marginal Zone. (Russian-Poland)**
IV. **Deep Marginal Zone (Depression) (Russian-Poland)**

Menelitic shales which are often mentioned in this article are bituminous, black or brown, finely bedded, and contain fish fossils. Sandstone intercalations and a hornstone horizon at the base are characteristic. The Menelitic shales are one of the most important features in the Carpathian Mountains and are found in almost all producing areas. They are of Middle and Upper Eocene age.

MAGURA ZONE
(German Poland)

The Magura Zone, being the least important from the point of view of petroleum production, was not geologically investigated in detail. This zone includes the oil field of Kleczany near Nowy-Sacz, Ropica-Ruska, Sekowa, Mecina-Wielka, Rozdziele, Szymbark, Harklowa, Pagorzyna and Wojtowa. The geology of these fields is, as already stated, very irregular and complicated. The most important characteristic is the lack of any Menelitic formations in the whole Magura Zone. The Magura sandstone of Oligocene age is found in almost all the above mentioned fields having a thickness of about 800 ft. This region is formed mostly of sandstone of very coarse texture with some thin layers of mica intercalated with dark grey and green shales. The Magura sandstone is underlain by thin beds of very hard sandstones intercalated with green shales. At greater depths, red and green shales with some siliceous sands are found. The formations situated below the Magura sandstone are of Eocene age. As to the value of petroleum production here, the area does not deserve important attention, although among its fields are some of the oldest in Poland. Oil was found in Mecina Wielka in the very early days of the Nineteenth Century. In that region oil has been produced since 1856, as far as can be proved, by means of mining and hand drilling of large diameter wells.

Mecina Wielka: The Mecina Wielka oil field is situated about eight miles east of Gorlice. This field was very active in 1875 when Poland had a great number of independent oil companies. At that time there were about 300 shallow hand-dug oil wells. Oil occurs in three different horizons at depths of 300 to 1,200 ft. in the Cretaceous Ropienka beds. The deepest well drilled in that region was abandoned at a depth of 2,600 ft. in the Ropienka formation. The proved producing area is about 5,000 acres. As of July 1, 1939 there were 27 producing wells. Current rate of production is about 620 bbl. per month. The nearest railroad station is at Gorlice. The principal lease-holders are Slaskie Tow. Naftowe Oil Co. and Morgenstern & Co. Oil Co.

Sekowa-Ropica Ruska: This oil field is situated three miles southeast of the city of Gorlice, has become almost inactive today, and has a very complicated structure. There are a great number of folds in the marginal part of the Magura zone. There are several oil horizons all in the Upper Cretaceous Inoceramous formations from 250 to 1,000 ft. This field was under intense development by 1878 and until December, 1938, it produced approximately 715,000 bbl. of oil. Proved producing area is about 6,500 acres. As of July 1, there were 32 producing wells with a production of 515 bbl. per month. Active oil companies Morgenstern & Co. Oil Co., Gorlicka Nafta Oil Co., Wladyslaw Dlugosz Oil Co., and a few independent small producers.

Szymbark: Szymbark field is situated three miles south of Gorlice and is now practically abandoned.

Total oil production since 1870 is estimated to be 210,000 bbl. Average daily production at present is about 0.4 bbl. per day per well. The proved producing area is 400 acres. As of July 1 the total number of wells was 12 with an average production of 110 barrels a month. The active oil companies here are Fr. Rzicha Oil Co., Gorlicka Nafta Oil Co., Morgenstern & Co. Oil Co., St. Haluch Oil Co., and the Bystrzyca Oil Co.

Harklowa - Pagorzyna - Wojtowa: The Harklowa-Pagorzyna-Wojtowa oil field is situated about 10 miles northeast of Gorlice. This field is among the oldest in Poland and has suitable geological conditions for application of the repressuring methods. Total production since 1877 to the end of 1938 is about 1,850,000 bbl. Present production is about 5,500 bbl. per month from 150 producing wells. The proved area is 6,700 acres. Active oil companies are Harklowa Oil Co., Ropita Oil Co., and Malopolska Oil Co.

MEDIAN ZONE
(German Poland)

Gorlice-Sanok Region: This region is situated on a great anticline which starts in Gorlice, having only the Oligocene and Eocene formations, but to the northeast shows Cretaceous formations. The region near Ciezkowice, north of Gorlice, is very complicated as the Magura formations are overthrust on Median formations in a very irregular way. These fields are situated on a series of folds in front of a marginal part of the Magura Zone. The main anticline has an east-west direction. There are many folds and some secondary thrusts over great distances. The thrust masses are generally composed of Cretaceous formations and are separated by the Krosno formations. The anticlines are wider in the Gorlice, Jaslo, and Krosno regions. Farther to the east towards Sanok, the anticlines become narrower.

The oil bearing formations are: Oligocene-I, II, III, Krosno beds, and Menelitic shale; Eocene-I, II, III, Ciezkowice sandstone and red and green shales and Cretaceous sandstones only in the lower part.

Kleczany: This oil field is the oldest one in Poland and is situated five miles north of Nowy-Sacz. Oil production started in 1856 and was distilled in one of the world's oldest refineries, built by E. Zielinski in Kleczany in 1864.

This field, once the most important in Poland, is at present almost abandoned, producing about one barrel of oil from 11 wells. Proved area is 2,500 acres. Since 1856 this field has produced 140,000 bbl. of oil. Active companies are Kleczany Oil Co. and Nafta Boryslawska Oil Co.

Kobylanka-Libusza-Lipinki-Kryg: This field is situated about four miles east of the city of Gorlice. From the tectonic point of view it is a part of the central Carpathic depression. On the East it is limited by the depression of Jaslo with the overthrust Magura facies. This overthrust fault limits

Poland's Per Capita Consumption of Petroleum Products

Year	Consumption of all Products	Annual per Capita				
		Gasoline	Kerosene	Fuel Oil	Lubricating Oil	All Products
	(Tons)	(Lbs.)	(Lbs.)	(Lbs.)	(Lbs.)	(Lbs.)
1930	451,000	7.06	10.37	5.07	3.97	27.50
1931	413,500	5.74	7.74	4.41	3.09	25.90
1932	387,000	5.07	6.62	4.41	2.87	24.26
1933	356,000	3.97	7.28	3.97	1.54	22.75
1934	355,000	3.97	7.74	4.41	1.77	21.40
1935	362,000	3.97	7.95	4.19	2.65	22.05
1936	383,000	4.64	8.17	4.64	2.87	23.08
1937	424,000	4.74	8.61	4.86	3.09	24.95
1938	467,000	7.06	8.61	4.86	2.43	26.20

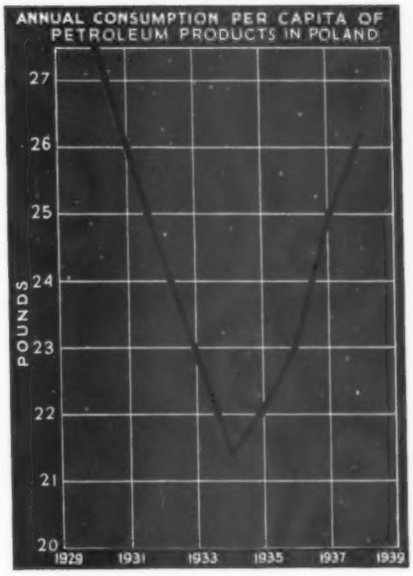
Comparative Annual Per Capita Consumption:—Great Britain, 551 lbs.; Holland, 386 lbs.; France, 254 lbs.; Germany, 185 lbs.; Poland, 26.20 lbs.

Export By Products

(Tons)

	Gasoline	Kerosene	Fuel Oils	Lub. Oils	Paraffin	Total*
1930	40,984	30,167	44,231	37,549	22,662	192,124
1931	70,524	37,110	42,455	30,574	22,113	219,475
1932	61,161	45,297	49,779	31,970	20,294	222,324
1933	57,459	53,109	44,214	32,347	22,205	226,991
1934	65,202	39,038	37,754	35,179	19,671	205,522
1935	47,545	35,299	43,035	22,019	19,179	170,164
1936	55,918	28,217	26,694	33,669	11,990	100,164
1937	47,456	10,489	27,825	18,859	17,119	126,844
1938	12,400	2,115	15,209	3,719	12,864	49,327

*Includes products not listed above.



it also from the South defining the field.

This region is one of the most important and most promising in Poland. Development started in 1865, but gained importance only in 1925. Recently the I. Morgenstern Co. Hanka No. 2 undertook reconnaissance drilling in the South Eastern Kryg in front of the Magura overthrust. This well, although not yet completed because of the war had oil shows in the Cretaceous and in the I Ciezkowice sandstone. Positive results in this well will mean the discovery of a new field.

Production until the end of 1938 was over 4,500,000 bbl. Proved producing area is 72,000 acres.

At present there are 650 producing wells with a production of 28,000 bbl. per month. Active oil companies: Morgenstern & Co., Oil Co., Cal.-Karp. Tow. Naftowe Oil Co., Favoryt Oil Co., Vacuum Oil Co. (Lipa), Gartenberg & Schreier Oil Co., Fr. Rzicha Oil Co., I. Krol Oil Co., and Pollon Oil Co.

Biecz-Zalawie: This field is situated seven miles northeast of the city of Gorlice. The geology is complex. The present oil fields are located on an anticline dipping toward North East. This anticline is broken by a great number of longitudinal folds. Oil is produced from three horizons, Eocene-Ciezkowice sandstone, sandstone, and Cretaceous beds from a depth of 600 to 2,100 ft. Development started in 1897. Up to the present time over 300,000 bbl. have been produced. Proved producing area is about 3,500 acres. As of July 1 there were 48 producing wells with a production of about 1,900 bbl. per month. Active companies: Wladyslaw Dlugosz Oil Co., Horta Oil Co., and Jednosc Oil Co.

Bobbka - Wietrzno - Rowne - Rogi: This field is the very first oil field in Poland, and is situated five miles south of Krosno. It consists of one anticline, very folded, and broken in many parts by a great number of transversal faults. The anticline is inclined in a northern direction.

Oil is produced from the Middle and Lower Cretaceous formations and from the Ciezkowice sandstone in the western part and only from the Eocene Ciezkowice beds in the eastern part. There are four different oil horizons, three in the Eocene, and one in the Cretaceous. The depth varies from 1,000 to 3,700 ft. Its development was started in 1850 by Ignacy Lukasiewicz, known as the father of the petroleum industry in Poland.

Until the end of 1938 over 5,500,000 bbl. were produced. At the present time there is no new drilling being done and the field is nearing the point of exhaustion with a present production of 5,500 bbl. per month from 95 producing wells. Producing area is about 21,000 acres. Active oil companies: Nafta Oil Co., Alma Oil Co., Cal.-Karp. Tow. Naft. Oil Co., and Pollon Oil Co.

Gorlice: The Gorlice oil field, better known as Magdalena field, is the newest oil field in Poland. It is situated on an unsymmetric fold in front of the Magura zone. The producing formations are slates of Oligocene age and the Ciezkowice sandstone. The Eocene Ciezkowice formations produce about 600,000 cu. ft. of gas daily. This field is most interesting as recent drillings in the vicinity of Magdalena in the direction of Ropica-Polska-Szymbark and Stroze indicates a considerable extension. Discovery in 1931 resulted from investigation of oil seepages. As of July 1, 1939 there were 40 producing wells with a production of about 2,500 bbl. per month. Proved area is 28,000 acres. Active oil company: Minerwa Oil Co.

Mecinka-Brzezowka-Roztoki-Jaszczew-Bialkowka-Sadkowa-Dobrucowa: This is one of the most important gas fields in Poland, situated three miles east of Jaslo and five miles west of Krosno. It is situated on an eight-mile fold, which is refolded in three minor folds and broken by transversal faults. The fold is an extension of the Potok anticline. Production of great quantities of gas and some oil comes from two main horizons, namely, Eocene Ciezkowice sandstone at 2,300 to 3,000 ft. and Cretaceous formations from 3,200 to 3,900 ft. The field is very active at the present time. There are 32 active wells of which 16 are gas wells and 16 oil and gas wells. From 1909 to the present this field has produced 65,000,000,000 cu. ft. of gas and over 200,000 bbl. of oil. Present production is 4,200 bbl. of oil per month, and about 56,000,000 cu. ft. of gas. Proved area is 56,000 acres. Active oil companies: Polmin Oil Co., Malopolska Oil Co., Nafta Borysławska Oil Co., and Jaslo-Jaszczew Oil Co.

Potok-Toroszowka: This field is situated about four miles east of Krosno. Like most Polish oil fields, it was discovered through oil seepages and surface indications, in 1887 and produced oil and gas. No drilling is being carried on at present. There are 107 oil wells with a production of about 12,000 bbl. of oil, and about 11,000,000 cu. ft. of gas per month. Until the end of 1938 over 5,500,000 bbl. of oil were produced. Proved area is 20,000 acres. Active companies: Gal.-Karp. Tow. Nafta Oil Co., Dabrowa Oil Co., W. Lozinski Oil Co., Jaslo-Potok Oil Co., Toroszowka Oil Co. and Petronafta, Oil Co.

Krosno-Kroscienko: This field is situated about one mile north of Krosno. The geology consists of three folds broken by transversal faults. The Krosno-Kroscienko fold is the extension of the big Potok fold. The producing formations are four different horizons in the Eocene at depths of 650 to 2,300 ft. Because of its irregularity it may be considered characteristic. It was discovered in 1888 through oil seepages. Present activity consists of cleaning and deepening the 46 producing wells which produce close to 2,400 bbl. of oil per month. From 1888 to 1938 this field produced about 1,100,000 bbl. of oil. Producing area is about 7,000 acres. Active companies: Gal.-Karp. Tow. Nafta Oil Co., Galicja Oil Co.

Weglowka: This field is situated about five

miles north of Krosno. It was discovered through surface indications by H. McGarvey, one of the pioneers of the Polish petroleum industry, in 1888. The geology consists of two parallel folds inclined to the north. The producing horizons are the Cretaceous sandstones at 400 to 1,500 ft. At present there are 85 producing wells with a production of 2,000 bbl. of oil per month. Until the end of 1938 this field produced over 2,000,000 bbls. Proved producing area is 6,000 acres. Active companies: Gal.-Karp. Tow. Nafta Oil Co., H. Macher Oil Co., W. Witting Oil Co. and Pory Oil Co.

Iwornicz-Klimkowka: This field is located about nine miles East of Krosno. It was discovered in 1886. The geology is very irregular and complicated, consisting of two separate anticlines—the northern and the southern anticline, and composed of a number of unsymetrical folds. The southern anticline is broken by transversal faults. In the southern anticline the producing formations are three different oil horizons in the Eocene Ciezkowice sandstone at a depth of 800 to 1,850 ft. In the northern anticline oil comes from three horizons in the Oligocene. The southern anticline is of much greater importance as far as oil production is concerned and until the end of 1938 it produced over 1,000,000 bbl. While the northern anticline produced only 50,000 bbl. At present the whole field has 60 oil wells producing about 1,900 bbl. of oil per month. Proved area is 20,000 acres. Active companies: Gal.-Karp. Tow. Nafta Oil Co., J. and E. Zaluski Oil Co., Ostoja Oil Co., and Lenartowicz & Rylscy Oil Co.

Zmiennica - Turzepole - Strachocina: This field is situated about five miles southeast of Brzozow. It was first discovered in 1880. The oil field is located on two parallel folds inclined to the north and broken in many separate blocks. Production comes from Eocene Ciezkowice sandstone at 200 to 2,500 ft. Until the end of 1938 over 700,000 bbl. of oil had been produced. At the present time there are 41 wells with a production of 2,000 bbl. of oil per month. Proved area is 2,000 acres. Active companies: Polmin Oil Co., Oterna Oil Co. and Szczesc Boze Oil Co.

Brzozow - Grabownica - Humniska - Starawies: This field is situated about 11 miles north of Sanok, and 18 miles east of Krosno. It was discovered in 1896.

The oil comes from the Upper Cretaceous formations in three different horizons at a depth of 1,650 to 3,300 ft. Although old, this field is still active. At present there are 62 wells with a production of 7,300 bbl. per month. Proved area is 16,000 acres. Active companies: Grabownica Oil Co., Galicja Oil Co., Humaniska Brzozow Oil Co., Starowsianka Oil Co., Brzozowsko-Iwonicka Ska Oil Co.

Sanok - Zagorz: This field is situated in the vicinity of Sanok, discovery occuring in 1884 as a result of oil seepages. While active in the early days of the present century, it is now practically abandoned. This field had produced, up to the end of 1938, close to 1,250,000 bbl. of oil. It has a present production of only about 150 bbl. per month. Proved area is 1,500 acres. Active companies: Tarnawa Oil Co. and Polmintar Oil Co.

Stankowa-Ropicnka-Leszczowate: This field is located 13 miles east of Sanok. Its development began on a commercial scale in 1885. Geology consists of long diapiric folds which are overturned to the south. Oil comes from a great number of horizons, irregularly located in the narrow area from the Oligocene and Kliwski'an sands. Since 1885 this field has produced over 5,500,000 bbl. of oil. It was extensively tested and a great number of wells were drilled. At present there are 385 oil wells producing about 13,500 bbl. of oil per month. Proved area is 3,500 acres. Active oil companies: Malopolska Oil Co., Ropienka Oil Co. and Standard Nobel Oil Co.

MARGINAL ZONE
(Russian-Poland)

The marginal zone is divided in two parts on the basis of differences in geological structures: Marginal Zone proper and the Deep Marginal Element (Zone)

In order to study its geology, it is necessary to consider separately each oil field situated on these zones.

The Marginal zone comprises the group sharply defined from the sub-Carpathian regions, and grades to a certain extent into the marginal formations in its southwest side. A vertical section contains from the bottom to the top: (1) Cretaceous formations (Jamna); (2) Eocene, (3) Menelitic shales; and (4) Dobrotow formations which are somewhat synchronic with the Krosno formations in the Median zone.

In the Boryslaw region, the Cretaceous formations, we can distinguish some Inoceramic layers intercalated with sandstones and marls, gray and black shales and clays; many veins of calcite intersect these formations in all directions. On top of these Inoceramic formations are situated thick layers of very hard sandstones intercalated with inserted green and red marls and clays. In the western part of the Marginal zone near Przemysl the sandstone situated on top of the Inoceramic formations is known as Jamna sandstone; in this are found many intercalated marls of Upper Cretaceous age.

The lower Eocene has the characteristic thick layers of green and red shales intercalated with thin layers of hard green sandstones. The Upper Eocene presents a series of Menelitic shales with many hornstones and sands. In the margins of upper parts, the shales are replaced by sandstones, and it then changes again to formations containing alternate layers of sandstones and gray, green, and brown shales known as Dobrotow formations or dark gray marl shales with sandstones known as Polanica formations. The Marginal zone includes the following more important oil fields: Strzelbice, Urycz, Schodnica, Boryslow-Tustanowice-Mraznica. The Deep Marginal Element includes the following fields: Rypne, Duba, Majdan, Bitkow, Pasieczna, Sloboda-Rangurska-Kosmacz.

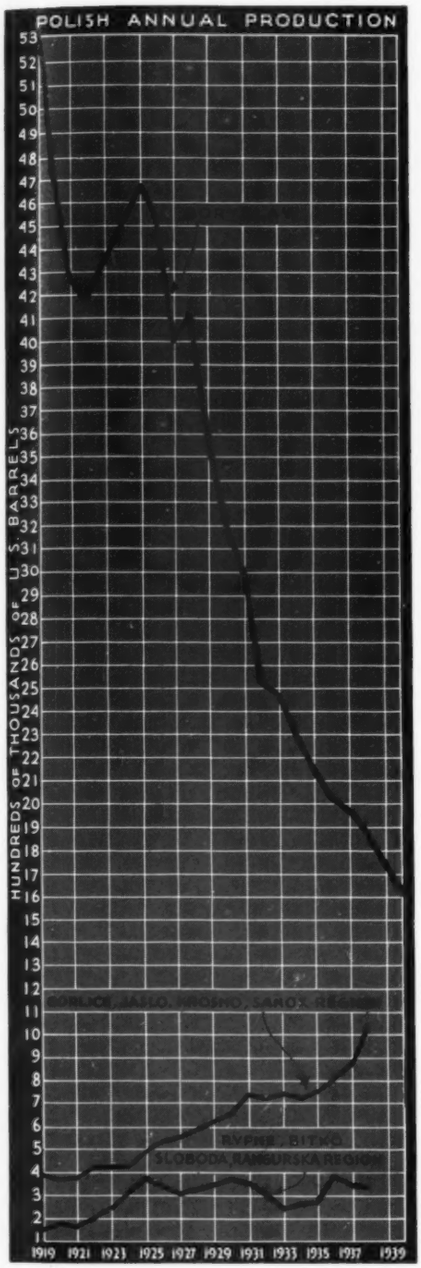
Strzelbice: This field is situated five miles west of Stary Sambor and in it saliferous clays of the Miocene grades down under the margin of the Carpathian mountains.

Only white Jamna sandstones are oil-bearing. The depth of oil wells varies with the location from the surface to 1,000 ft., the deeper wells being to the south. The oil fields of Strzelbice were discovered in 1881. Producing area is about 2,500 acres. Total production until 1938 was about 650,000 bbl. The present production is about 1360 bbl. per month. Active oil companies: Limanowa Oil Co. and Zofja Oil Co.

Schodnica: The Schodnica field is situated about five miles south of Boryslaw on the overthrust of the Marginal Carpathians. For many years, the Schodnica fields were the most important fields in Poland and, at the present time, they are among the leading producing fields. Discovery occured in 1872, although there are records that in 1859 there was one well producing oil for domestic use. The depth of crude oil production varies from 1,000 ft. to 1,600 ft. Producing area is about 20,000 acres. The Schodnica field produced until 1938 over 17,100,000 bbl. of oil, which amounts to about 7.2 percent of total Polish production. Present production is about 25,000 bbl. per month. Active oil companies: Gazy Ziemne Oil Co., Galicja Oil Co., Schodnicka Ska. Naft. Oil Co., Brzozowski & Winiarz Oil Co. and S. R. Backenroth Oil Co.

Urycz: This field is situated six miles south of Boryslaw and east of Schodnica and was discovered in 1891. The geology consists of a secondary anticline in the southern part of the slice (skiba) of Skole. In the southeast the anticline of Urycz steepens and, as a result, the Eocene is covered with Menelitic shales; these deepen under the Polanica formations. The oil-bearing formations are the upper Eocene, over the red shales, and the Jamna sandstones, the latter yielding a bigger production. Wells range in depth from 800 to 1,050 ft. Indications of greater potential production exist in the deep Cretaceous formations in the southeast direction. Proved area is about 25,000 acres. Until 1938 this field produced over 3,000,000 bbl. of oil. Present rate of production is about 4,950 bbl. per month. Active oil companies: Uryckaska Oil Co., Gazy Ziemne Oil Co., Schodnicka Ska. Naft. Oil Co., S. R. Backenroth Oil Co.

Boryslaw-Tustanowice-Mraznica: The Boryslaw - Tustanowice - Mraznica oil fields are by far the most important fields in Poland. They were discovered in 1855 by Robert Doms. The geology of this field is more complicated and irregular than that of any other field. There are seven different producing formations, namely: (1) Overthrust formations, (2) Polanica formations, (3) Menelitic shales, (4) Boryslaw sandstone, (5) Middle Eocene, (6) Lower Eocene, and (7) Jamna sandstones. The depth of the above formations varies considerably depending on the location of the well. This field has produced until now about 70 percent of the total Polish



Oil production of the three principal regions of Poland: Although Boryslaw is by far the most important its production has been declining sharply.

oil production which amounts to 177,000,000 bbl. of oil. The rapid decline of production at the present time can be explained by the exhaustion of the already exploited horizons, but the development of adjacent fields may show that the producing areas of the Boryslaw region extends farther in all directions. The highest production of this field came in 1909 when it produced about 13,800,000 bbl. of oil. This field is also a gas field. At present there are 784 wells of which 130 are producing only gas at a rate of 17,500,000 cu. ft. per month. Current oil production is 154,000 bbl. of oil per month. Proved producing area is about 150,000 acres. Active oil companies: Malopolska Oil Co., Nafta Oil Co., Galicja Oil Co., Premier Oil Co., Fanto Oil Co., Limanowa Oil Co. and Schodnicka Nafta Oil Co.

Rypne-Duba: This field is situated 21 miles southeast of Stanislawow and was discovered in 1891. Producing formations in the fields of Rypne-Duba are the Menelitic shales which are a part of the northwest plunging end of the Sliwki anticline, and in the southern part of these fields are Eocene and Menelitic shales intercalated by thrusting with some Cretaceous formations. The thin layers of sandstone in the Menelitic shales are oil-bearing. The Rypne-Duba oil fields, although very old, were never sufficiently developed, and therefore still have important potential production both in the undeveloped areas and in the vicinity of these fields where the structure extends far to the southeast. Producing area is about 62,000 acres. Until 1938 over 1,700,000 bbl. of oil were produced. At present there are 137 producing wells with a production of 8,500 bbl. of oil per month. Active oil companies: Malopolska Oil Co., Alfa Oil Co., Rypne Oil Co.

Majdan Rosulna: This field is situated five miles southeast of Rypne and was discovered in 1890. It is situated on the same tectonic formations as Rypne and part of Boryslaw. Formations constituting its structure are the Polanica formations, situated mostly in the southwest part of Majdan, Menelitic shales, and Eocene green shales. In the north are, first saliferous clays, the Polanica, Menelitic, and Eocene formations. Oil appears in a few different horizons separated by water formations from 130 to 1,000 ft. Producing area is about 17,000 acres. Until 1938 this field produced over 375,000 bbl. of oil. At present there are 110 producing wells with a production of about 1650 bbl. of oil per month. Active oil companies: Majdanska Ska Oil Co., Podkarpackie Tow. Naftowa Oil Co., T. Kozak Oil Co. and W. Zuckerberg Oil Co.

Bitkow: This field is situated 22 miles southwest of Stanislawow. It was discovered in 1870. The geology of these fields is composed of two different tectonic units: (a) The overthrust element, and (b) The deep element. Depth of wells varies from 1,600 to 3,200 ft. Proved producing area is about 70,000 acres. Total oil production up to the end of 1938 has been about 6,500,000 bbl. At present there are 118 producing wells with a production of about 13,400 bbl. per month. Active oil companies: Malopolska Oil Co., Standard Nobel Oil Co., Nafta Oil Co., Fanto Oil Co. and Segal Oil Co.

Pasieczna: This field is located 20 miles southwest of Stanislawow and was discovered in 1882. The geology is similar to that of Bitkow. Depth of producing formations varies from 800 to 1,200 ft. Proved producing area is about 9,000 acres. Total production until the end of 1938 was about 820,000 bbl. of oil. At present there are 41 producing wells with a production of about 2,380 bbl. of oil per month. Active oil companies: Premier Oil Co., Standard Nobel Oil Co., Bonariva Oil Co.

Sloboda-Rungurska: This field is situated 11 miles southwest of Kolomyja and 16 miles southeast of Nadworna, and is one of the oldest fields in Poland. It was mentioned as an oil-producing field in 1771. It is one of the most interesting fields in the Deep Depression. The oil wells of Sloboda-Rungurska are situated on the southern part of the great anticline. The producing area is about 45,000 acres. The total production until the end of 1938 was about 2,600,000 bbl. of oil. Present production is rather small, being about 960 bbl. of oil per month from 52 producing wells. Active oil companies: Sloboda-Rungurska Oil Co., A. Rosenkranz Oil Co. and Wschodnio-Malopolska-Spolka-Wiertnicza Oil Co.

Daszawa: This field is situated six miles northeast of Stryj and about 21 miles east of Boryslaw and was discovered in 1912. It is the most important gas field in Poland. The geology consists of a dome of (1) Middle Miocene beds, (2) Pokucie beds, (3) red marls with sandstones which are the Dobrotow beds. The gas formations belong to the Tortonian age and occur in two different horizons. The main gas production comes from a depth of about 2,400 ft. Initial pressure is about 850 lbs. per square inch. The gas is dry with an average composition of 94.5 percent methane, 2.2 percent of oxygen, 3.2 percent of nitrogen, and about 0.1 percent of carbon dioxide. Total gas production since 1920 until the end of 1938 was about 52,000,000,000 cu. ft. Producing area is about 60,000 acres. Present production is about 12,000,000 cu. ft. per day. This field has a promising future as the same formation extends over a radius of about 28 miles. Active oil companies: Polmin Oil Co., Malopolska Oil Co. and Gazolina Oil Co.

Kosmacz: This field is situated 14 miles southeast of Kolomyja and was discovered in 1899. The oil production comes from the Cretaceous formations in different horizons from a depth of 230 to 720 feet. The oil fields of Kosmacz are characterized by absence of water, and are now practically abandoned as producers. The proved producing area is about 2,500 acres. At present there are only 10 producing wells with a production of about 310 bbl. of oil per month. Until the end of 1938 this field produced over 210,000 bbl. of oil. Active oil companies: Kosmacka Ropa Oil Co. and Premier Oil Co.

CONCLUSION

It will be noted from the foregoing review of the oilfields of Poland that there are several promising areas for further exploration and for more intensive exploitation by the most modern methods which heretofore have not been common in Poland. In view of the investment required, the time that would be consumed before any substantial return was obtained, and the uncertainty of the political and economic outlook for the immediate future, it appears likely that such development will be postponed indefinitely.

WORLD OIL P

All figures furnished direct to WORLD PETROLEUM by governments, except where otherwise specified

U. S. BARRELS

	Oct. 1938	Nov. 1938	Dec. 1938	Jan. 1939	Feb. 1939	Mar. 1939	Apr. 1939	May 1939	June 1939	July 1939	Preliminary Figures Aug. 1939	Sept. 1939
United States	101,830,000	98,567,000	102,287,000	102,490,000	93,475,000	106,768,000	105,510,000	110,541,000	104,607,000	110,937,000	80,865,000	112,990,000
Soviet Union[4]	17,400,000	17,250,000	17,050,000	17,000,000	17,500,000	18,000,000	18,100,000	18,500,000	18,700,000	18,200,000	18,100,000	18,000,000
Venezuela	17,352,171	16,356,204	16,744,163	16,489,347	14,899,459	15,646,415	16,980,646	17,676,580	16,430,693	18,015,249	18,743,714	16,838,928
Iran[5]	7,136,578	7,221,080	6,624,726	6,408,776	4,982,000	6,999,058	7,244,370	6,801,192	6,900,000[1]	7,000,000[1]	7,000,000	6,895,888
Netherland India: Sumatra	3,049,196	3,015,432	3,177,589	3,129,007	2,969,950	3,393,286	3,400,503	3,602,543	3,498,094	3,557,020	3,550,123	3,500,632
Borneo	1,123,102	1,090,009	1,114,535	1,115,570	1,000,937	1,134,647	1,123,474	1,173,509	1,154,341	1,156,942	1,111,810	1,165,582
Java[9]	523,623	515,160	529,658	535,297	503,441	550,097	509,355	530,273	514,565	565,181	559,096	550,144
Ceram	50,444	45,750	45,773	49,200	55,219	67,442	82,914	89,975	77,305	73,962	71,767	73,853
Roumania	4,028,750	3,847,324	3,969,300	3,953,671	3,665,559	3,973,053	3,743,911	3,840,413	3,684,366	3,902,333	3,958,612	3,905,830
Mexico[15]	3,313,182	3,098,725	3,245,558	2,470,000[1]	1,960,000[1]	3,118,021	3,140,120	2,945,000[1]	3,100,000[1]	3,245,000[1]	3,700,000[1]	4,050,000
Iraq	2,431,949	2,420,143	2,290,777	2,414,878	1,955,122	2,699,272	2,608,216	2,663,827	2,721,992	2,807,402	2,735,000	2,640,307
Colombia	1,891,825	1,863,838	1,908,879	1,710,565	1,633,621	1,818,765	1,826,928	1,899,735	1,851,716	1,798,271	1,950,966	1,833,505
Trinidad	1,594,480	1,503,489	1,664,322	1,652,412	1,499,197	1,630,789	1,569,298	1,645,040	1,575,321	1,620,564	1,640,000	1,636,985
Argentina[1]	1,360,000	1,358,000	2,028,000	1,534,000	1,430,000	1,556,000	1,549,000	1,556,000	1,530,000	1,556,000	1,556,000	1,559,683
Peru[3]	1,331,111	1,303,990	1,321,883	1,251,162	1,103,878	1,210,288	1,151,193	1,078,426	1,051,265	1,100,000[1]	1,100,000	1,157,218
Bahrein[6]	708,962	613,281	623,907	647,988	610,766	658,822	629,336	626,009	628,812	671,892	698,714	647,595
Burma[7]	604,885	591,029	651,495	698,103	424,277	600,863	635,000[1]	640,000[1]	635,000[1]	640,000[1]	640,000	631,350
Canada[8]	685,088	445,514	489,303	531,564	356,218	384,461	558,779	713,450	821,308	723,500[1]	731,000	605,803
Brunei[2]	477,459	484,207	510,500	506,467	453,571	492,374	466,328	486,815	472,162	498,650	499,000	497,454
Great Germany: Old Reich[14]	331,792	307,433	313,206	332,592	330,584	395,181	373,126	409,782	373,510	391,098	410,000	384,573
Ostmark[13]	43,697	29,000[1]	34,259	33,609	46,666	43,293	54,375	64,840	78,944	85,131	87,000	62,592
Slovakia and Moravia	13,747	10,502	9,879	10,546	9,000[1]	10,000[1]	9,000[1]	10,000[1]	9,000[1]	11,000[1]	11,000	10,520
Poland	330,412[1]	318,000[1]	316,702	325,293	298,259	333,618	326,400[1]	333,800[1]	318,000[1]	330,000[1]	330,000	330,264
Japan[10]	220,451	224,255	173,737	224,885	218,594	222,368	218,594	221,229	220,814	221,758	223,000	284,835
British India[11]	210,348	197,809	217,528	253,874	213,185	236,042	215,000[1]	230,000[1]	215,000[1]	230,000[1]	230,000	235,560
Ecuador	192,702	185,669	192,882	195,556	171,634	181,938	175,896	193,753	113,710	206,868	204,115	193,720
Saudi Arabia	136,947	152,632	139,038	155,605	170,865	215,270	234,742	281,325	392,932	342,558	350,000	538,136
Sarawak[12]	223,165	115,952	118,512	116,030	105,714	115,980	110,982	112,572	106,077	109,797	112,000	116,571
Egypt[13]	208,377	211,841	221,156	308,946	301,102	330,445	328,376	369,972	426,808	436,519	440,000	375,951
Italian Empire: Albania[16]	Nil	Nil	6,220	99,206	67,914	125,440	244,576	81,839	79,971	140,025	89,000	111,276
Italy	8,622	8,533	7,937	7,511	8,090	8,324	7,797	7,253	7,181	6,843	7,600	7,736
France	42,296	40,797	48,000[1]	42,000[1]	40,000[1]	42,000[1]	41,000[1]	42,000[1]	41,000[1]	42,000[1]	42,000	42,653
Hungary	49,800[1]	43,303	47,671	49,199	49,578	67,261	67,000[1]	70,000[1]	67,000[1]	70,000[1]	70,000	65,210
Bolivia[1]	8,800	8,500	9,000	8,800	7,000	8,700	8,500	8,700	8,500	8,700[1]	8,700	7,893
Other Countries[17]	48,000	50,000	48,000	50,000	35,000	50,000	48,000	50,000	48,000	50,700	50,700	50,000
WORLD TOTAL	168,961,961	163,494,401	168,181,095	166,801,659	152,551,400	173,090,513	173,292,735	179,496,852	172,460,387	180,751,963	151,875,917	181,998,247

[1] Estimated.
[2] Includes natural gasoline (naphtha) production.
[3] International Petroleum Company and Lobitos Oilfields, Ltd., figures combined.
[4] Russian Saghalin included with U.S.S.R.
[5] Anglo-Iranian Oil Company, Ltd., figures revised —fuel oil returned to the ground has been deducted.
[6] Bahrein Petroleum Company, Ltd., figures.
[7] Does not include Assam or Punjab, which are listed together under British India.
[8] British Malayan Petroleum Company, Ltd., figures.
[9] Includes Madura.

Comparative Cumulative Daily Averages in Barrels

	Jan.-Sept. 1939	Jan.-Sept. 1938
United States	3,399,938	3,335,421
Soviet Union	594,772	565,905
Venezuela	555,751	505,372
Iran	220,627	210,042
Netherland India: Sumatra	112,092	93,343
Borneo	37,131	34,742
Java	17,648	19,760
Ceram	2,350	1,703
Roumania	126,842	136,309
Mexico	101,568	92,011
Iraq	85,150	86,486
Colombia	59,685	58,304
Trinidad	53,002	47,523
Argentina	50,647	44,655
Peru	37,375	43,777
Bahrein	21,318	23,632
Burma	20,309	20,703
Canada	19,875	19,474
Brunei	16,017	14,431
Great Germany: Old Reich	12,455	10,614
Ostmark	2,038	963
Slovakia and Moravia	330	354
Poland	10,716	10,470
Japan	7,530	6,933
British India	7,541	6,254
Ecuador	5,997	6,176
Saudi Arabia	9,822	243
Sarawak	3,684	4,275
Egypt	12,154	3,369
Italian Empire: Albania	3,806	1,463
Italy	250	297
France	1,370	1,422
Hungary	2,107	709
Bolivia	276	294
Other Countries	1,584	355
WORLD TOTAL	5,612,892	5,422,853

Official Crude Oil Production Figures for 1932 to 1938 (Revised) in Barrels

	1938	1937	1936	1935	1934	1933	1932
United States	1,213,254,000	1,279,160,000	1,098,516,000	996,596,000	908,065,000	905,656,000	785,159,000
Soviet Union	206,192,000	201,856,661	199,635,921	184,008,033	175,635,783	155,596,429	155,927,997
Venezuela	173,506,497	187,675,477	155,270,840	148,809,057	136,098,681	117,113,940	115,615,782
Iran	78,320,840	78,109,001	62,977,950	57,520,488	57,902,092	54,440,075	49,516,697
Netherland India: Sumatra	34,538,128	33,451,511	30,469,428	28,004,595	26,336,011	22,345,172	18,570,928
Borneo	12,812,383	12,960,072	13,068,910	13,529,185	14,335,543	15,003,175	15,228,615
Java	6,955,283	7,152,931	3,618,293	3,462,440	3,778,920	3,600,816	3,837,142
Ceram	607,622	537,436	375,823	311,872	273,698	285,335	309,957
Roumania	48,366,000	52,395,725	63,532,846	61,270,072	61,849,306	53,919,708	53,651,978
Mexico	38,505,824	46,455,687	41,027,915	40,240,563	38,171,946	34,000,830	32,805,496
Iraq	32,404,000	30,603,660	29,913,150	27,410,983	7,639,849	1,094,915	87,840
Colombia	21,581,588	20,297,543	18,756,110	17,597,655	17,337,900	13,156,126	16,415,214
Trinidad	17,736,176	15,502,989	13,237,030	11,671,224	10,894,363	9,561,353	10,126,121
Argentina	17,076,223	16,354,717	15,457,960	14,297,025	14,021,901	13,690,556	13,138,747
Peru	15,908,279	17,459,112	17,593,069	17,056,555	16,314,381	13,257,318	9,899,265
Bahrein	8,297,998	7,762,264	4,644,635	1,264,807	285,072	31,377	902
Burma	7,499,498	7,847,553	7,587,718	7,181,113	7,278,859	7,114,311	7,073,437
Canada	6,936,479	2,995,023	1,507,931	1,447,204	1,410,895	1,145,333	1,044,412
Brunei	5,387,214	4,397,038	3,296,938	3,302,905	2,705,350	2,035,656	1,200,026
Great Germany: Old Reich	3,850,044	3,148,300	3,076,858	2,967,438	2,204,402	1,656,602	1,594,807
Ostmark	370,038	221,266	50,092	44,347	27,965	5,765	894
Slovakia and Moravia	130,867	122,790	126,603	136,580	177,797	121,695	126,603
Poland	3,828,438	3,799,862	3,869,575	3,901,881	4,011,336	4,174,079	4,219,634
Japan	2,511,184	2,487,841	2,403,072	2,294,878	1,872,837	1,504,412	1,683,439
British India	2,330,209	2,161,653	1,978,329	2,037,810	1,921,863	1,628,803	1,743,878
Ecuador	2,257,278	2,161,436	1,942,467	1,731,785	1,636,619	1,619,902	1,597,641
Saudi Arabia	495,135	64,968	19,777	Nil	Nil	Nil	Nil
Sarawak	1,624,882	1,655,565	1,547,882	1,776,593	1,942,591	2,206,815	2,329,733
Egypt	1,561,231	1,163,267	1,262,666	1,255,151	1,527,252	1,653,535	1,071,976
Italian Empire: Albania	437,597	380,292	219,693	41,218	17,500	11,437	9,212
Italy	106,083	112,700	129,653	128,615	162,449	213,534	242,563
France	516,240	507,067	534,063	529,664	700,000	786,366	755,146
Hungary	330,829	13,910	100	Nil	Nil	Nil	Nil
Bolivia	106,620	123,123	104,746	163,295	157,875	111,973	41,907
Other Countries	243,000	70,000	37,100	32,300	64,000	54,100	73,300
WORLD TOTAL	1,966,585,707	2,041,168,442	1,797,791,150	1,652,023,331	1,516,760,036	1,438,797,443	1,305,100,199

PRODUCTION

Figures in U. S. barrels of 42 gal.—Conversion ratios used are weighted averages for individual countries

METRIC TONS

	Oct. 1938	Nov. 1938	Dec. 1938	Jan. 1939	Feb. 1939	Mar. 1939	Apr. 1939	May 1939	June 1939	July 1939	Aug. 1939	Preliminary Figures Sept. 1939
United States	13,785,028	13,343,306	13,846,893	13,874,374	12,653,243	14,445,677	14,275,470	14,956,000	14,153,000	15,009,700	10,941,000	15,274,000
Soviet Union[4]	2,387,000	2,366,000	2,339,000	2,332,000	2,400,000	2,469,000	2,480,000	2,536,000	2,590,000	2,500,000	2,480,000	2,300,000
Venezuela	2,564,234	2,417,054	2,474,385	2,438,207	2,201,782	2,323,150	2,521,254	2,624,585	2,439,598	2,674,870	2,783,081	2,500,212
Iran[5]	943,864	955,040	876,168	849,376	660,400	927,608	960,120	902,208	918,000[1]	920,000[1]	920,000[1]	900,364
Netherland India: Sumatra	409,288	404,756	426,522	420,001	398,651	434,424	435,476	461,214	447,842	455,386	454,503	448,167
Borneo	150,752	146,310	149,602	149,741	134,354	146,543	142,552	150,238	147,784	148,117	142,339	149,172
Java[3]	70,285	69,149	71,095	71,852	67,576	70,426	65,210	67,888	65,877	72,357	71,578	70,432
Ceram	6,771	6,141	6,144	6,604	7,412	8,634	10,615	11,519	9,897	9,469	9,188	9,455
Roumania	550,000	525,232	541,884	536,091	497,025	538,719	507,645	520,734	499,575	536,761	536,761	529,604
Mexico[13]	491,862	460,025	481,823	367,000[1]	291,000[1]	457,859	461,104	432,000[1]	455,000[1]	477,000[1]	543,316[1]	594,713
Iraq	326,086	324,503	312,734	323,797	262,151	360,817	348,648	356,079	363,854	375,271	376,000[1]	352,935
Colombia	263,669	259,768	266,046	238,406	229,371	253,663	254,802	264,956	258,258	250,805	272,101	255,719
Trinidad	224,385	211,580	234,214	232,537	210,413	229,306	220,717	231,370	221,564	227,927	231,000[1]	230,237
Argentina[1]	194,000	193,500	288,930	218,000	202,000	221,000	220,000	221,000	217,500[1]	221,000	221,000	222,177
Peru[2]	177,893	172,805	175,667	166,281	146,286	159,774	151,973	142,367	138,782	146,000[1]	146,000[1]	152,768
Bahrein[6]	96,660	83,585	85,009	88,264	83,180	89,811	85,920	85,353	85,840	91,642	95,348	88,372
Burma[7]	83,548	81,634	89,985	82,992	58,602	96,423	87,800[1]	90,000[1]	87,800[1]	90,000[1]	90,000[1]	87,203
Canada[8]	86,545	56,280	61,812	67,151	45,000	57,640	71,109	90,793	117,244	92,000[1]	93,000[1]	77,221
Brunei[9]	62,607	63,491	66,939	66,410	59,474	65,749	62,271	65,007	61,996	65,474	65,500[1]	65,317
Great Germany: Old Reich[14]	47,788	45,865	45,111	47,562	47,614	56,654	53,357	58,205	53,412	55,927	58,300[1]	54,994
Ostmark[15]	6,519	5,600[1]	5,111	5,014	6,962	6,454	8,106	9,666	11,289	12,691	13,000[1]	9,331
Slovakia and Moravia	2,008	1,534	1,443	1,545	1,500[1]	1,500[1]	1,400[1]	1,500[1]	1,400[1]	1,600[1]	1,600[1]	1,550
Poland	43,590	42,000[1]	42,688	43,819	40,202	44,968	44,000[1]	45,000[1]	41,000[1]	45,000[1]	45,000[1]	44,516
Japan[10]	31,376	31,913	24,724	32,003	31,094	31,631	31,095	31,469	31,410	31,544	31,721	40,517
British India[11]	29,054	27,322	30,045	35,065	29,445	32,602	30,000[1]	33,000[1]	30,000[1]	33,000[1]	33,000[1]	32,674
Ecuador	27,310	26,314	27,336	27,715	24,325	23,986	23,190	25,544	25,539	27,272	26,910	25,540
Saudi Arabia	18,570	20,697	18,590	21,100	23,169	29,190	31,821	38,148	41,078	46,450	47,500	71,751
Sarawak[12]	16,150	15,204	15,540	15,214	13,862	15,838	14,197	14,401	13,343	13,811	14,300[1]	14,663
Egypt[13]	29,789	30,285	31,617	44,390	43,045	47,193	46,897	52,838	60,955	62,342	62,800[1]	53,692
Italian Empire: Albania[16]	Nil	Nil	41,674	14,869	10,179	18,801	36,657	12,266	11,980	20,987	13,000[1]	16,678
Italy	1,071	1,060	986	933	1,005	1,034	968	901	892	850	950[1]	961
France	5,923	5,713	6,000[1]	5,900[1]	5,500[1]	6,000[1]	5,700[1]	6,000[1]	5,700[1]	6,000[1]	6,000[1]	5,983
Hungary	6,400[1]	5,602	6,167	6,619	6,670	9,049	9,000[1]	9,500[1]	9,000[1]	9,500[1]	9,500[1]	8,773
Bolivia[1]	1,100	1,000	1,130	1,100	900	1,000	1,000	1,000	1,000	1,000[1]	1,000[1]	1,023
Other Countries[17]	6,700	7,000	6,700	7,000	6,000	7,000	6,700	7,000	6,700	7,100	7,100	7,000
WORLD TOTAL	23,147,825	22,407,268	23,099,714	22,838,932	20,899,392	23,689,123	23,706,774	24,555,749	23,624,109	24,738,853	20,843,396	24,697,714

[10] Japanese Saghalin, Taiwan (Formosa) and Hokkaido included with Japan.
[11] Excluding Burma.
[12] Sarawak Oilfields, Ltd., figures.
[13] Anglo-Egyptian Oilfields, Ltd., figures.
[14] Prussia, Thuringia and Baden.
[15] Formerly known as Austria.
[16] Italian imports of Albanian crude oil.
[17] Estimate representing Morocco, Cuba, New Zealand, Barbados, Greece, Algeria, Yugoslavia, Australia, Great Britain, Kuweit and China.
[18] Official Figures—Petroleos Mexicanos.

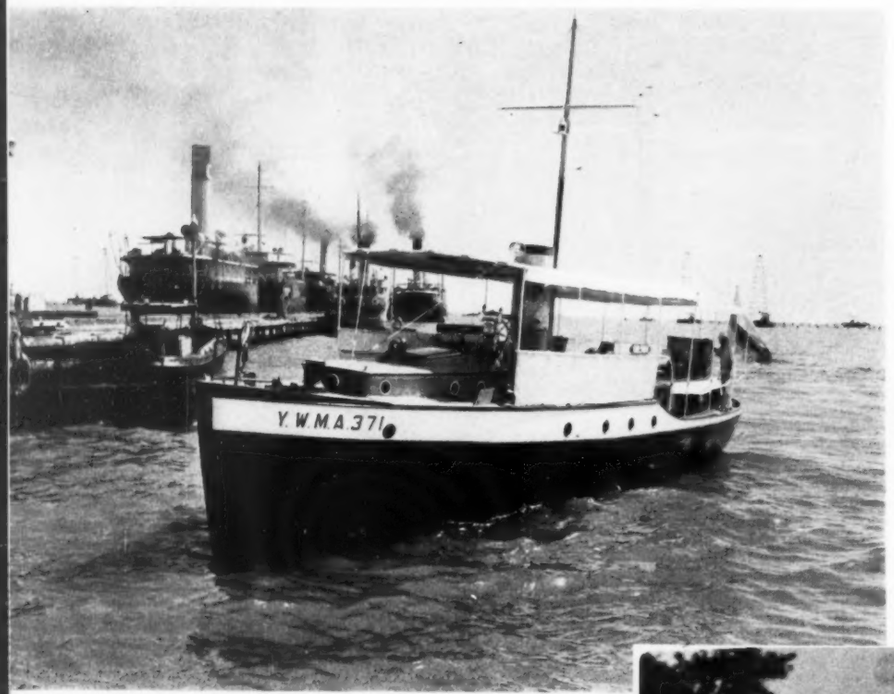
Comparative Cumulative Daily Averages in Metric Tons

	Jan.-Sept. 1939	Jan.-Sept. 1938
United States	460,009	447,815
Soviet Union	80,904	79,332
Venezuela	82,442	74,687
Iran	29,150	27,780
Netherland India: Sumatra	14,489	12,534
Borneo	4,801	4,663
Java	2,282	2,652
Ceram	303	228
Roumania	17,223	18,206
Mexico	14,941	13,170
Iraq	11,427	11,597
Colombia	8,344	8,126
Trinidad	7,454	6,688
Argentina	7,193	6,368
Peru	4,946	5,764
Bahrein	2,907	3,170
Burma	2,823	2,874
Canada	2,605	2,460
Brunei	2,114	1,883
Great Germany: Old Reich	1,780	1,514
Ostmark	302	155
Slovakia and Moravia	49	52
Poland	1,441	1,379
Japan	1,070	982
British India	1,058	863
Ecuador	842	875
Saudi Arabia	1,282	32
Sarawak	475	561
Egypt	1,736	481
Italian Empire: Albania	569	216
Italy	31	36
France	193	198
Hungary	284	91
Bolivia	33	36
Other Countries	225	50
WORLD TOTAL	767,743	737,152

Official Crude Oil Production Figures for 1932 to 1938 (Revised) in Metric Tons

	1938	1937	1936	1935	1934	1933	1932
United States	163,228,715	172,822,797	148,707,864	134,912,143	122,913,903	122,601,191	106,289,292
Soviet Union	28,859,000	27,867,025‡	27,384,900	25,241,100	24,092,700	21,330,100	21,389,300
Venezuela	27,845,286	27,733,926	22,945,299	21,990,373	20,112,115	17,293,193	17,085,334
Iran	10,358,495	10,330,480	8,329,289	7,607,500	7,657,970	7,200,093	6,548,941
Netherland India: Sumatra	4,662,836	4,490,137	4,114,710	3,759,006	3,535,035	2,999,352	2,492,742
Borneo	1,719,783	1,739,607	1,773,545	1,815,998	1,924,234	2,013,849	2,043,707
Java	933,595	960,125	499,097	464,757	510,320	483,331	515,187
Ceram	81,560	72,139	50,446	41,862	36,738	38,300	41,605
Roumania	6,603,000	7,153,000	8,704,000	8,394,000	8,473,355	7,387,000	7,350,321
Mexico	5,716,423	6,896,657	6,090,842	5,973,955	5,666,857	5,049,109	4,870,175
Iraq	4,345,000	4,126,185	4,079,066	3,724,231	1,048,108	147,943	118,887
Colombia	3,007,935	2,844,251	2,614,092	2,452,635	2,416,432	1,833,606	2,287,835
Trinidad	2,472,943	2,181,676	1,862,796	1,642,446	1,533,122	1,345,532	1,425,009
Argentina	2,432,857	2,330,063	2,202,304	2,036,903	1,997,706	1,950,499	1,871,882
Peru	9,099,885	2,313,691	2,331,454	2,260,903	2,161,990	1,756,867	1,311,856
Bahrein	1,130,734	1,058,557	635,555	173,072	39,008	4,293	123
Burma	1,039,960	1,083,391	1,047,593	991,456	1,004,951	982,233	976,589
Canada	876,016	378,430	190,495	182,820	178,233	144,686	131,937
Brunei	707,123	576,545	470,991	471,842	386,478	290,808	171,432
Great Germany: Old Reich	552,074	453,451	444,600	427,400	317,500	238,600	229,700
Ostmark	63,468	33,010	7,473	6,616	4,172	860	120
Slovakia and Moravia	19,282	17,936	18,665	19,946	25,971	17,776	18,493
Poland	504,678	501,301	510,630	614,760	529,200	550,670	556,680
Japan	356,328	341,040	341,976	326,580	266,520	212,667	239,567
British India	322,125	298,450	273,137	281,072	265,341	224,879	240,767
Ecuador	319,877	306,326	275,293	245,434	231,947	229,578	226,423
Saudi Arabia	66,683	8,070	2,447	Nil	Nil	Nil	Nil
Sarawak	200,126	217,085	221,126	253,799	277,513	315,259	332,819
Egypt	223,058	166,298	177,491	176,436	214,671	232,437	265,055
Italian Empire: Albania	65,313	56,760	32,760	6,152	2,500	1,707	1,375
Italy	13,178	14,000	16,106	15,977	20,180	26,526	27,046
France	72,106	71,008	74,788	74,172	98,025	110,120	105,758
Hungary	42,798	13,910	13	Nil	Nil	Nil	Nil
Bolivia	13,262	15,487	13,197	20,540	19,858	14,085	5,284
Other Countries	34,080	10,000	5,300	4,600	9,100	7,700	10,500
WORLD TOTAL	277,989,582	279,482,814	246,449,340	226,610,486	207,971,753	197,034,849	179,181,741

Foreign Oil Legion



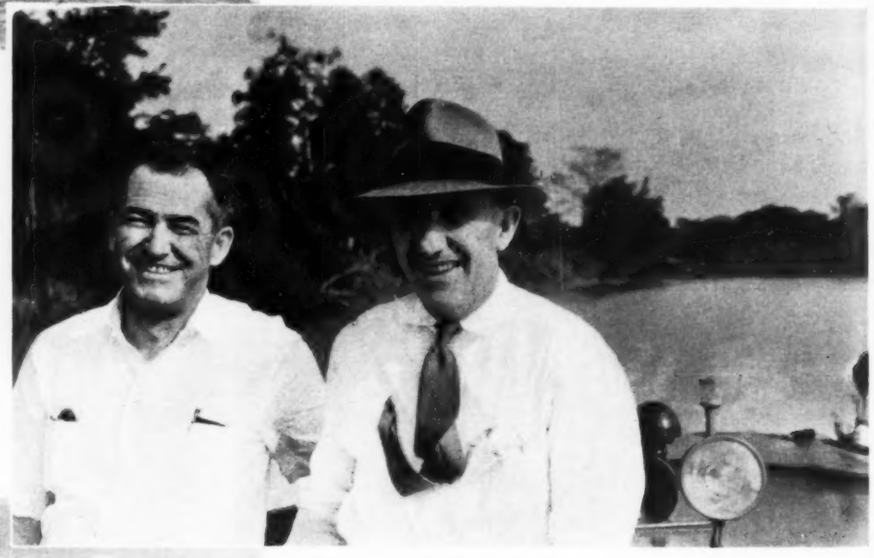
Left, M. G. O. C. launch for the trip down Lake Maracaibo and below, R. W. Parkinson (left) and R. D. Clay of the C. P. C. (Shell) on an inspection of the pipeline from Colon.

IN ORDER to make the Venezuelan issue of WORLD PETROLEUM, which will be published in December of this year, outstanding in regard to editorial content and illustrations, it was decided to send the managing editor accompanied by a leading industrial photographer to South America during the past summer. The main purpose of the trip was to gather editorial material and photographs of such a nature as to convey to WORLD PETROLEUM readers an adequate impression of the extent and importance of the Venezuelan oil industry.

Photographs, would of course, play an important part in visualizing the conditions under which operations are carried on in Venezuela. WORLD PETROLEUM, therefore, was fortunate in securing the services of Robert Yarnall Richie, who has devoted a large part of his time to petroleum subjects in the Mid-Continent, Texas and the Gulf Coast and whose work has appeared in leading illustrated journals for several years past. His first studies of petroleum subjects were, in fact, published in WORLD PETROLEUM some years ago and immediately excited very favorable comment.

Boarding the Pan American clipper at 7:15 on the morning of the 29th one became aware of the increased tempo of oil operations in South America while still hundreds of miles north of the fields. Every flight carries oil men, refinery engineers, tanker experts and representatives of petroleum equipment firms as passengers bound for remote parts of Latin America.

WORLD PETROLEUM'S representatives spent some time in Caracas and had the honor of lunching with the Ministers of Fomento and Public Works and with a number of technical and administrative experts from the Petroleum Department. Government plans for geological surveys of mineral deposits in the more remote sections of the country as well as projects for public works are not confined to blue prints or theoretical plans. Dr. Victor M. Lopez, geologist in Fomento, had just returned from a survey of the Southeastern section of the country which was completed with the aid of a well equipped expedition and an aeroplane.



In Caracas the managing editor had an opportunity for discussion with a number of oil company officials culminating in an interview with the President of the Republic, General Eleazar Lopez Conteras.

Leaving Caracas the editor and photographer spent two months visiting all the important oil operations in Venezuela, returning to New York at the end of September.

Twin Motor Grumman amphibian of the C.P.C. (Shell) on the Rio Escalante. World Petroleum's representatives made the trip from Maracaibo to Salito with Mr. Clay and Mr. Parkinson in this ship.

EUROPEAN WAR'S Influence on World Bunkering Trade

By B. Orchard Lisle

ONE anticipated effect of war in Europe upon the petroleum industry was an immediate increase in the demand for fuel oil. The navies of the world are powered by liquid fuel and their peacetime consumption is at the rate of something like 6,000,000 metric tons. Under active hostilities the warships and auxiliaries of Britain and France at least must increase their use of oil substantially through the extension of patrols and the convoying of merchant ships. War creates a heavy demand for a variety of materials and supplies and normally would add to the activities of commercial shipping which also depend very largely on oil fuel.

In this respect, as in some others, the present war has not followed a traditional pattern thus far in its course. If the German fleet remains bottled up at Kiel or other bases, fleet activities may be circumscribed. It appears, moreover, that the operations of United States shipping may be drastically restricted by terms of the embargo law. The needs of patrols and convoys will not be lessened, however, and as time goes on the character of the war may change. In any case a substantial rise in bunker oil demand appears inevitable though it may not make itself felt as quickly or as strongly as at first expected.

The greatest percentage increase may be expected on the part of the various navies, both neutral and belligerent, although, if world war experience is a criterion, this rise may not necessarily be immediate. In Winston Churchill's memoirs of his previous term as First Lord of the Admiralty, he says of 1914-15 that naval oil consumption was "estimated at a total in the first ten months of war of 1,000,000 tons; the actual consumption was 800,000 tons."

TABLE 1

World Fuel Oil Consumption by Navies in 1937

Navy	Tonnage	Horse-power	Consumption (tons)
British Empire	1,256,000	6,450,000	1,503,700
United States	1,146,000	5,996,000	1,178,000
Japan	813,000	4,524,000	886,000
France	516,000	2,730,000	657,000
Italy	425,000	3,620,000	497,000
Soviet Russia	193,000	483,000	214,000
Germany	135,000	695,000	140,000
Spain	100,000	546,000	106,000
Argentina	100,000	350,000	106,000
Netherlands and Netherland India	88,000	616,000	94,300
Sweden	85,000	255,000	90,000
Chile	75,000	150,000	71,000
Brazil	59,000	118,000	62,700
China	52,000	105,000	57,000
Turkey	44,000	88,000	45,700
Norway	40,000	60,000	43,000
Greece	37,000	74,000	39,300
Portugal	26,000	55,000	28,500
Denmark	16,000	34,000	17,100
Finland	15,000	37,000	16,600
Cuba	15,000	30,000	16,600
Other Countries	150,000	300,000	140,000
World Total	5,386,000	27,316,000	5,999,900

Based on figures estimated by V. R. Garfias, R. V. Whetsel and J. W. Ristori, Foreign Department, Cities Service Oil Co., N. Y.

That was the situation in the early stages of the world war, but later on, Mr. Churchill observes, "The Admiralty demands for fuel oil by 1917, had jumped from 13,000 tons to 330,000 tons per month. . . . So depleted were the stocks of naval fuel oil that the fleet had to restrict its exercises and was becoming seriously handicapped in its duties. . . . In June, 1917, available stocks of fuel oil were 950,000 tons against a monthly consumption of 400,000 tons."

This situation called for drastic measures, and with the aid of American oil it was quickly remedied. "In April of the following year," still quoting Mr. Churchill, "the monthly consumption had risen to 460,000 tons and stocks to 1,500,000 tons. In October 1918 the monthly consumption was nearly 500,000 tons and stocks had risen to 1,800,000 tons. . . . By the end of the War practically every ship in the British fleet was burning oil." So, from 1914 to 1918 the Admiralty's fuel oil demands rose from about 80,000 tons to 500,000 tons monthly.

On the basis of these statistics, and bearing in mind that the first two months of the current conflict have failed to bring about any notable naval engagements, it does not seem probable that military consumption of bunker fuel oil is likely to rise to great heights until the conflict becomes more active. When fighting does become more intensified, an increase commensurate with that of the period from 1914 to 1918 is not unlikely. The rise should be more rapid due to the fact that all the navies of the world are dependent on oil almost to the total exclusion of coal, whereas many coal-burning vessels were still in service during the earlier conflict.

In time of peace, the navies of the world do not involve themselves in unnecessary expense, and comparatively few vessels are at sea, except when engaged in their annual maneuvers; ships which are on cruise travel at reduced speeds to hold down fuel consumption.

Today the situation is different. The British navy is actively patroling the North Sea in an endeavor to keep the German fleet in its home ports and to cut off the Reich's overseas imports by a strict blockade. At the same time, both British and French forces are kept busy in Atlantic and Mediterranean waters hunting down submarines and convoying their own and neutral merchant ships bound for Allied ports. This convoy work, of course, is maintained chiefly by destroyers and gunboats, which must again travel at somewhat reduced speeds in order not to leave the merchantmen behind. In view of these different commitments, an immediate increase of about 125 to 150 percent in allied naval fuel oil consumption would not be at all surprising. Further growth in consumption should result from additions to the fleet next spring.

An interesting estimate of world consumption of petroleum products for military purposes was made by Garfias, Whetsel and Ristori last year; the figures are given in detail in the accompanying Table I. These authorities calculated the 1937 consumption of fuel oil by the British and French navies to be about 1,503,700 tons and 657,000 tons respectively, or about 180,000 tons per month.

The statisticians admitted "that the opportunities for error in an estimate of this nature are obvious and ever present. To quote an example. . . . the Japanese navy, as a result of the hostilities in China, obviously needed during the year more fuel oil than, say, a corresponding American fleet. . . . We have made what we believe to be adequate allowances for these and other similar conditions and, therefore, feel that our conclusions do represent a fair approximation to the actual facts." The writer is inclined to believe that these allowances could not have been very great, for the ratio of fuel consumption to horsepower is practically the same for both of the two countries cited, although admittedly naval action has not been a major feature of the Sino-Japanese war. Nevertheless, these are the most reliable estimates available.

So much for allied naval fuel oil consumption, while the demand from the Reich fleet is not likely to be reflected elsewhere than in Roumania until it leaves the North Sea for broader waters.

Neutral navies also should show an appreciable increase in bunker oil consumption as a result of the European War. The small navies of the Scandinavian countries, for instance, are very active in trying to

TABLE II

U. S. Consumption of Marine Fuel Oil (in Tons)

	1938	1937	1936	1935	1934	1933	1932
Merchant Vessels :							
Fuel and Diesel Oil	8,680,000*	12,141,400	11,474,800	10,654,400	9,894,600	10,063,600	10,361,600
U. S. Navy :							
Fuel Oil	1,716,550	1,118,750	1,080,520	1,149,600	929,780	897,190	921,670
Diesel Oil	33,540	34,590	31,090	34,760	25,560	22,900	21,800
U. S. Coast Guard :							
Fuel Oil	64,580	48,570	.....	.....	.....	.....	.....
Diesel Oil	8,580	11,670	.....	.....	.....	.....	.....
Total	10,503,250	13,354,980	12,586,410	11,838,760	10,850,940	10,983,690	11,305,070

Based on figures from U. S. Bureau of Mines; Division of Finance, U. S. Coast Guard; Bureau of Supplies and Accounts, U. S. Navy Department. *Preliminary estimate.

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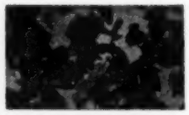

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TABLE III

Comparison in Use of Coal and Oil Fuels

Propulsion Type	Percent of Total Tonnage 1914	1935	1936	1937	1938	1939
Oil fuel for boilers	2.65	30.65	30.38	29.84	29.57	29.63
Oil for internal combustion engines	0.45	17.42	18.89	20.74	22.45	24.36
Coal	88.84	50.15	49.10	47.89	46.54	44.67
Sailing ships, etc	8.06	1.78	1.63	1.53	1.44	1.34

Compiled by Lloyd's Register for 1939-1940.

prevent molestation of their nationals in the Baltic and North seas. But an equally great rise in percentage, and a much vaster increase in actual tonnage, should take place in the requirements of the United States and the various republics of South America. The reason for anticipating such a rise in demand from non-combatant countries is the establishment of a 300 mile neutral zone around the Americas.

In order to make this zone effective, the various republics having navies will find it necessary to patrol the waters on either side of the two continents, and the nations chiefly concerned are the United States, Argentina, Chile and Brazil. The United States government, for example, has ordered a large number of immobilized world war destroyers to be recommissioned for patrol work along the Atlantic, while the coast guard also has become more active. Therefore, a substantial increase in fuel oil consumption should be the result of these operations.

The popularity of Diesel engines, due to their higher efficiency, plus the substitution of bunker oil for coal for burning under marine boilers because of the relative economy and simplicity of operation, have been important factors in increasing mercantile oil demands since the world war.

In general, world shipping has increased from 24,444 vessels of 45,403,877 gross tons in 1914 to 29,763 aggregating 68,509,432 tons, an increase of 5,319 ships and 23,105,555 gross tons, or 50.9 percent. As may readily be seen this very substantial rise has been due entirely to the increased number of petroleum powered vessels, for the decrease in ships using coal fuel is considerable. The increase for all types of power-propelled vessels has been rather erratic during the period under review, while that for oil-burning vessels has been comparatively steady. Of the two types deriving their power from petroleum, the projection for Diesel motored ships is still rising sharply, whereas the curve for oil-fired steamships started to flatten out in the middle twenties and shows only a minor tendency to increase—its slight rise is a result of renewed construction in the United States, where motorships never have been widely adopted.

An excellent comparison of the respective employment of coal and oil fuel at the present time and the beginning of the world war is brought out by Table III, which also gives the trend during the past five years and clearly tells the story of the growth of oil power in world shipping. It will be noted that in 1914 oil supplied only 3.10 percent of marine power while in 1939 it amounts to almost 54 percent. Coal, responsible for nearly 89 percent before the earlier war, has decreased by about 13,000,000 tons to only 44.67 percent in 1939.

The number and tonnage of oil-fired vessels in commercial operation under different flags is detailed in Table IV. Until the details of the Neutrality Act before the U. S. Congress were settled, it was hard to calculate with any certainty the effect which the current European War is likely to have on American shipping. A large amount of the world's merchant tonnage has been laid up during recent years because of the shipping depression, but increased demand for raw materials of all kinds is expected to bring virtually every idle ship that will float back into active service. Needless to say, a large proportion of the idle tonnage is comprised of coal-burning steamers, but many burn oil or have facilities for dual-firing.

Inasmuch as Britain seems to have included in its wartime fuel economy measures, the limitation of coal consumption, it seems quite probable that the dual-fired ships which previously took on cheap coal in English

TABLE IV

Oil-Burning Merchant Ships of the World

Country	Steamers No.	Steamers Gr. Tons	Motorships No.	Motorships Gr. Tons	Total Oil-Fired No.	Total Oil-Fired Gr. Tons
Great Britain and Ireland	849	5,298,778	1,014	4,586,056	1,863	9,884,834
Canada	117	302,747	35		152	414,826
British Empire	196	450,350	234	296,480	430	746,830
United States	1,421	7,525,769	486	790,418	1,907	8,316,187
Argentina	82	176,162	*	*	82*	176,162*
Belgium	8	41,431	81	157,247	89	198,678
Brazil	§	§	28	60,803	28§	60,803§
Denmark	23	72,744	180	594,584	203	667,328
France	213	1,159,218	191	427,207	404	1,586,425
Germany	124	857,021	529	1,115,096	653	1,972,117
Greece	§	§	18	12,300	18§	12,300§
Netherlands	167	834,728	750	1,332,846	917	2,167,574
Italy	229	1,197,354	174	669,179	401	1,866,533
Japan	153	732,675	697	1,518,041	850	2,250,716
Norway	230	665,291	622	2,999,847	852	3,665,138
Panama	44	133,930	*	*	44*	133,930*
Soviet Russia	31	116,471	130	343,281	161	459,752
Spain	26	116,633	102	168,436	128	185,069
Sweden	16	62,843	199	699,453	215	762,296
Venezuela	28	68,838	*	*	28*	68,838*
Other Countries	243	762,663	318	690,620	561	1,453,283
Total	4,202	20,575,676	5,913	16,600,826	10,115	37,176,502

*Motorships included with other countries.
§Steamships included with other countries.
Compiled from Lloyd's Register for 1939-1940.

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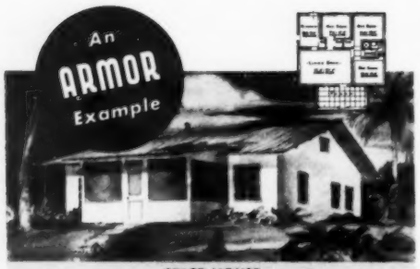

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Admittedly a large proportion of the increased shipping activity during the initial months of the current conflict has been in respect of coal burners, but ship-building programs the world over have been speeded up and replacements will burn oil. Very few vessels are built today to operate on coal fuel. One of the most important of these programs is that of the U. S. Maritime Commission, whose chairman, Rear Admiral Emory S. Land, announced at the annual meeting of the Propeller Club of the United States early in October, that despite the outcome of American marine legislation the commission intends to go ahead with its plans for construction of about 50 vessels a year until America has an adequate merchant marine. All these new vessels will be burning fuel or Diesel oil, and will increase the world demand as they are put in operation.

Congress has decided to restrict American shipping, but this should not affect world bunker oil consumption to a marked extent, as it is probable that other neutral vessels will be withdrawn from the trade routes which may be followed by U. S.-flag bottoms and these ships will operate in belligerent waters. Demand for marine tonnage should keep freight rates high and encourage other non-combatants to risk war losses for quick profits.

Conservatively, the demand for marine oil bunkers by merchant vessels should increase by about 30 percent in the immediate future, while additional construction on the ways should result in further demands next year. Altogether, the outlook for the companies engaged in oil bunkering is rather favorable.

PRORATION

(Continued from page 23)

wells than are necessary to extract the oil but also for drilling in advance of economic requirements, and hence capital is employed prematurely and in unnecessary amounts. In this way the rate of capital-flow into production has been distorted, and the disequilibrium created by this circumstance, in my judgment, was one of the causes of the decline in crude oil prices in October, 1938. The maintenance of equity amongst operators and balance in capital-flow can be effected through the recognition of the available oil as the unit of proration and the utilization of this factor as the basis for lease allowables. In this manner the pressure to drill unnecessary wells would be reduced promptly and

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County of New York }

Before me, a notary public in and for the State and county aforesaid personally appeared E. W. Mayo, who, having been duly sworn according to law, deposes and says that he is the editor of the WORLD PETROLEUM and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation) etc., of the aforesaid publication for the date shown in the above caption, required by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business manager are: Publisher, Russell Palmer, 95 River St. Hoboken, N. J. Editor, E. W. Mayo, 95 River Street, Hoboken, N. J. Managing Editor, none. Business Manager, Frank Palmer, 95 River Street Hoboken, N. J.

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E. W. MAYO
(Signature of Editor)

Sworn to and subscribed before me this 27th day of October 1939.

[SEAL] CLARA BRUN
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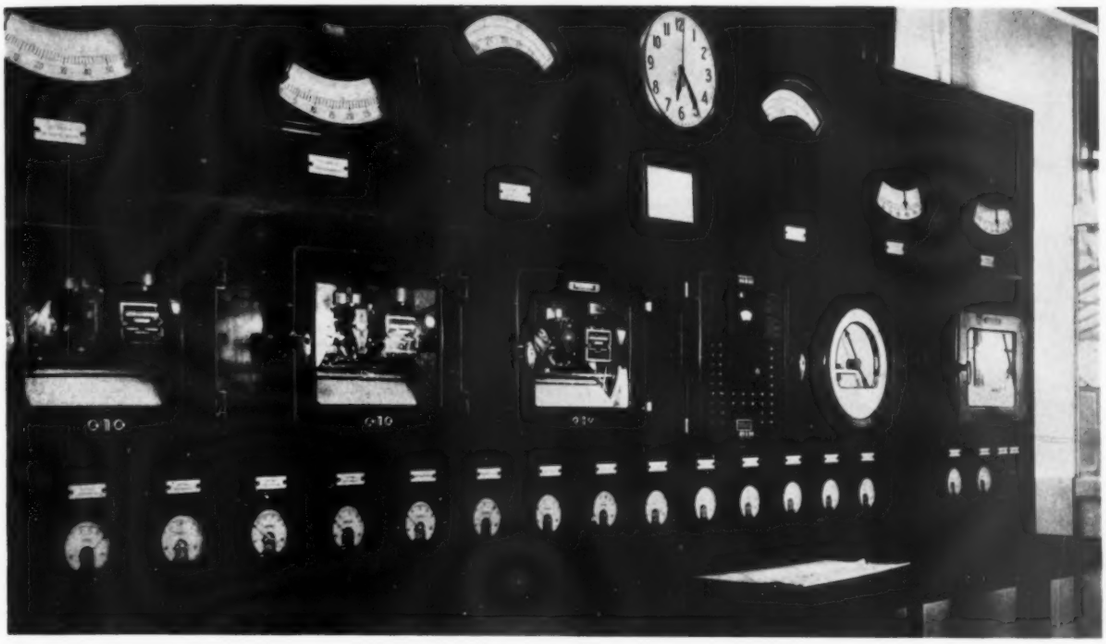

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the conservation of capital made an essenti by-product of the conservation of oil.[4] On this is done, some of the most perplexing di ficulties now plaguing the regulatory bodi and the oil operators will be resolved.

The ideal proration, as I see the matter, a system of state-enforced engineering quot keyed to optimum rates of production, as de termined by exacting technical investigatio with market demand equated to this quot system by a free and flexible price. The f attainment of this end will require time, bo to perfect the engineering knowledge nece sary to establish the base for its functioni as well as to permit the gradual accommod tion of investments and trade channels to th new plane of equilibrium. The existing ma chinery of proration is adapted to this pu pose and the employment of market-deman quotas is a necessary instrumentality to effe tuate the transition. A concerted move to ward the engineering objective, sponsored b the Interstate Oil Compact Commissio coupled with a planned attack by the sta regulatory bodies upon the flaws in prorati administration that lead to unnecessary dril ing, if conducted in an atmosphere of flexib crude oil prices suitable for preserving balan in the internal structure of the industry— these conditions, I believe, would enable th industry to progress to a position of maximu serviceability to both the public and itself.

I have examined the literature, exchange experience with many engineers, and studie the reservoir condition in a large number pools, and the data thus far available are sug gestive that the optimum-rate concept is ou that can be worked out by the engineers as practical yardstick. The data likewise ind cate that our known reserves are no large than necessary to support such rates of outp although existing market demands would no conform closely to the component parts of supply conditioned by a rigid application optimum rates or as likely to manifest itse where over-investment in unnecessary drillin has taken place. But these preliminar studies support the conclusion that, far fro being distant from an ideal conservation mea ure, proration has this goal almost with its reach.

As to the future, proration faces two av nues of change. It may evolve either into rigid system of pervasive regulation und which all freedom of initiative will be thro tled, or else into an engineering device f maximizing the resource and minimizing cos with an effective by-product of economic st bilization. A regimentation in the form direction will come if the system is imple mented with further controls, under the urg for a quick resolvement of temporary ma adjustments; whereas time, technology, an economic statesmanship can bring to a suc cessful outcome one of the most significan experiments in the economic field today. Th social advantage of the latter course is tha under it proration will be encouraged furthe to support the principles of mass production

[4]Much can even be accomplished on the part of the administrative bodies by the simple expedient of introducing an acreage factor into the allocation formula.

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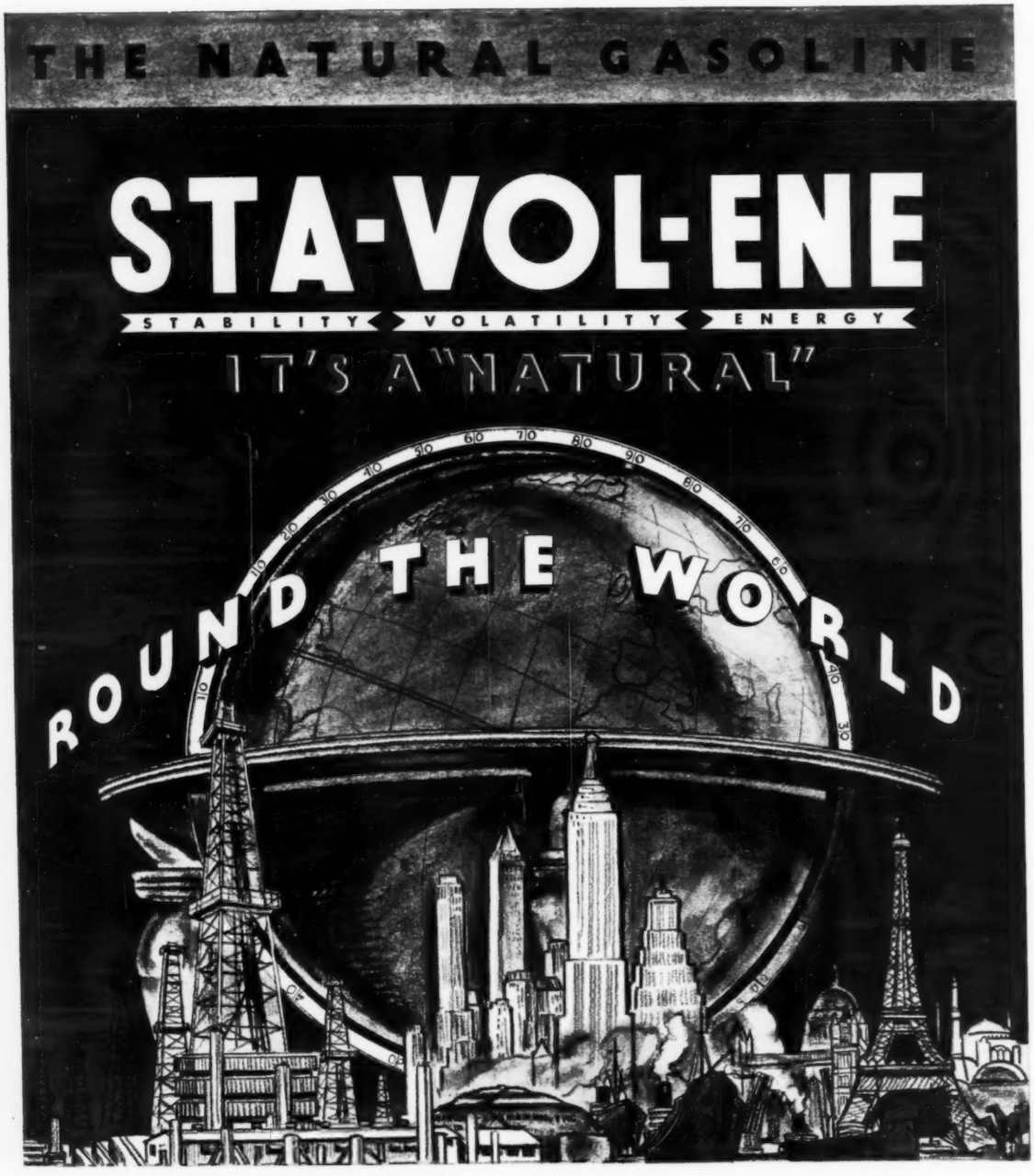

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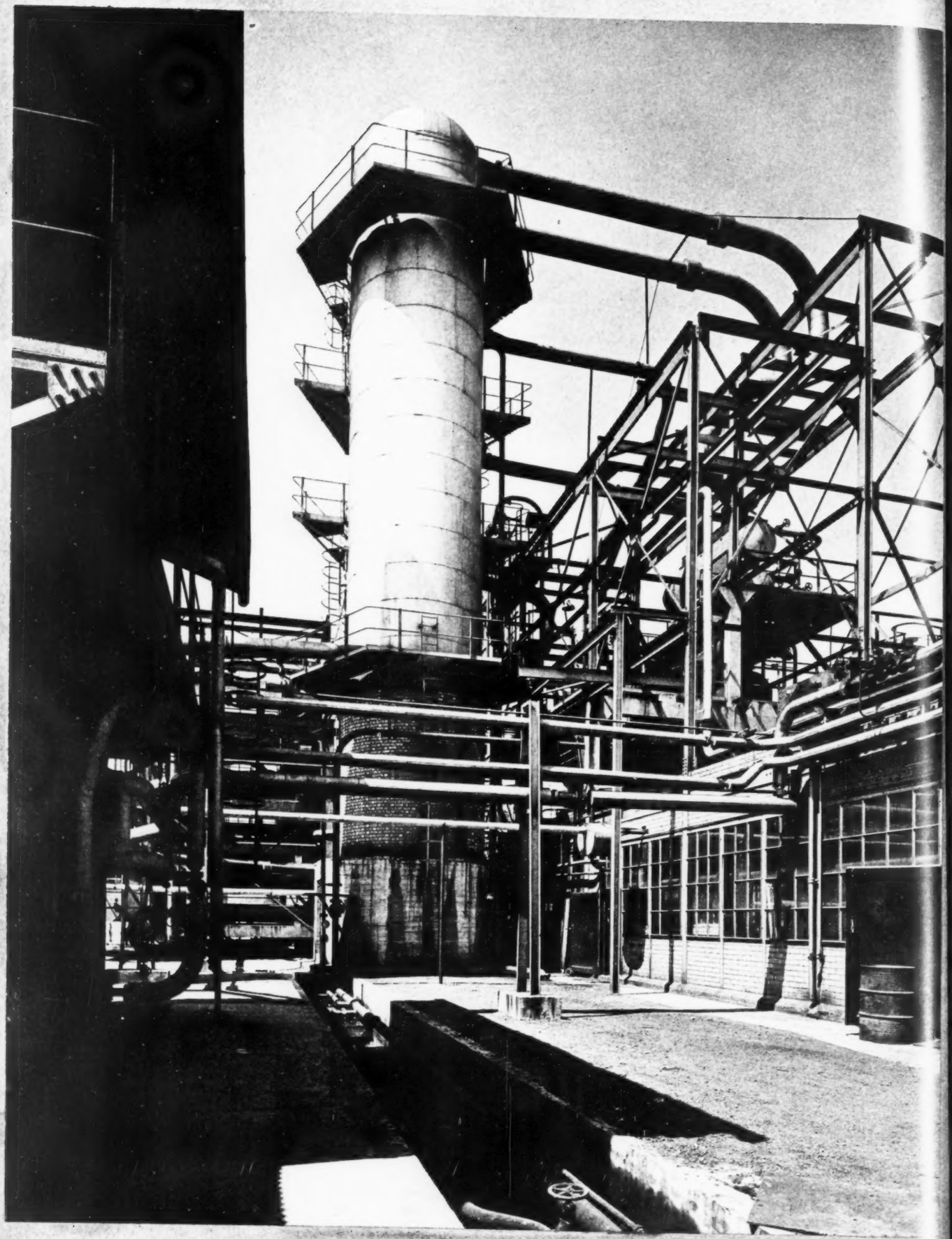

MANCHESTER REFINERY

EDITORIAL

CONSERVATION THROUGH REFINING PROGRESS

IN its broad aspects conservation is directed to the most advantageous use of the force or the commodity to which it is applied. It does not imply abstention from use although arguments advanced in connection with it sometimes appear to be based on that assumption. In its practical application conservation is the antithesis of waste, not merely of physical wastes but of economic or social wastes as well.

A certain amount of waste occurs in almost every operation of industry and daily living. The tailings of every mine contain ore that could be recovered only at a cost greater than its current value. Every manufacturing establishment has its scrap heap; every family fills a daily garbage pail. Much of the progress in industry for decades past has consisted in finding uses for by-products formerly cast aside as of no value. But until such useful employment can be found it is impossible to put an end to these losses because the demand for the main product must be met. Thus we have the distinction between avoidable and unavoidable wastes. In a millennial world there will be no such thing as unavoidable waste but until science and invention have done their perfect work the phrase will have a practical meaning.

In the petroleum industry conservation is especially desirable because oil is an important natural resource and—so far as we know now—an irreplaceable one. But conservation can come only with knowledge of the means by which waste can be prevented. Producers and refiners of an earlier day are sometimes pilloried for reckless waste though actually they employed the only processes they knew by which to obtain the products in demand at the time. In their day gasoline was waste because no practical means had been found of putting it to work. Yesterday the residues of distillation and cracking were largely waste but today it is discovered that they can be made to yield products of the highest value.

Conservation of petroleum usually is discussed as though it were confined to regulatory measures for preventing avoidable losses of crude oil above or below ground through wasteful methods of production. The losses take various forms. This side of conservation, the phase that the public hears most about, is of first rate importance and there is no intention here to deprecate its value. With all due deference to those in private and public life who are engaged in the movement for the improvement of its methods and its broader application it may be pointed out that there is also another and a very important conservation effort which is being pressed steadily forward.

Preventing Processing Wastes

AMONG the great petroleum conservationists must be counted the chemists and engineers who have devoted themselves to eliminating wastes in the processing of oil after it is produced. By study and experimentation they have been able to make a barrel of crude go twice as far as it did twenty years ago in the yield of that most valuable product, gasoline. Dissecting a drop of oil they have been able by use of heat and pressure or through the mysterious influence of catalysts to change the form of its constituent molecules, to rearrange them in new combinations and thereby to enable them to perform tasks that would have been impossible in their original state.

The chemical engineers of the petroleum industry have wrested many secrets from their studies of the physiology of oil and of the gases and residues that constituted the former wastes of refining. In so doing they have multiplied instead of diminishing the problems remaining unsolved. This is so because the more they have learned about the character and habits of the constituents of petroleum, the greater have become the possibilities of combining or separating them to create superior products to serve established uses or entirely new products to serve new and valuable purposes. There must be a limit to the possibilities of this kind of alchemy, but it lies so far ahead that no man now living can pretend to visualize it.

The bearing of all this research and experimentation upon the conservation of the world's supply of petroleum is not difficult to trace. Gas that is blown from the refinery stack is waste but when that same gas is made to supply a unit of power capable of propelling a motor car or airplane a certain distance it conserves the product that otherwise would be used up in performing this work. Whenever the skill of inventor or processor is able to raise a product from an inferior to a superior use, that is, from the performance of some humble task to one of greater value to mankind, the same result is achieved. Hundreds of millions are expended every year in the effort to find ways of improving petroleum products and making them do more and better work, but the benefits to users are measured in the thousands of millions.

Conservation by Cracking

THE GREAT and classic example in the oil industry of savings effected by inventive skill is in the application of cracking. Cracking is exactly what its name implies, the breaking up of the elongated chains of carbon atoms of slow combustion into smaller and more volatile fragments that can be consumed rapidly in an internal combustion engine. When the rapid spread in the use of motor cars brought about a swiftly growing demand for gasoline the method of obtaining this product was by simple distillation, the heating of crude oil in columns, causing the lighter fractions to rise to the top where they could readily be drawn off. Presently it was discovered that the combination of a greater degree of heat with pressure made it possible to obtain more gasoline from the residues of the distillation process. The practical importance of this development is demonstrated by the fact that more than half the gasoline consumed at the present time is produced by cracking. To obtain without cracking the same amount of gasoline produced in the United States in 1938 would have required nearly 2,500,000,000 barrels of crude instead of the 1,165,015,000 barrels actually consumed. As a conservation measure therefore cracking saves in the United States alone more than a thousand million barrels of oil yearly and in the period from 1920 to date has saved the enormous quantity of over 16,000,000,000 barrels or practically the amount of present estimated available reserves.

Measured by the financial yardstick cracking has been the most important development in the refining art but it was only the first in a long series of improvements all tending to the same result.

Formerly it was possible to produce high grade lubricating oil only from special Pennsylvania crudes but with the advent of solvent treating methods, this monopolistic position was lost and other less valued oils acquired the qualities of standard lubricants under one or another of these refining techniques.

Hydrogenation, polymerization, isomerization, alkylation and their numerous variants, by the dispersion, transformation and recombination of molecules, effect savings either by converting previous wastes to useful purposes or by enabling more power to be derived from a unit of given proportions. Other noteworthy savings come from the adjustment of methods so that the maximum amount of a desired product or products is obtained and from the blending of different crudes so as to permit the attainment of desired results in an easy and economical manner.

Superior vs. Inferior Use

WHILE the improvement of refining methods and results has been inspired as much perhaps by the desire to obtain products of high quality and to meet the demands of engine builders which grow more exacting from year to year as by conscious efforts to eliminate wastes it remains true that practically every advance represents an increase in the amount of useful work that a barrel of crude can do when subjected to the various changes that science and skill can accomplish in the processing of this raw material. Put in another way, a certain amount of work can be accomplished by a steadily decreasing quantity of oil from year to year. This progress has not reached its end and that fact puts an encouraging aspect on the much discussed possibility of an early exhaustion of the world's supplies of petroleum.

As one new process follows another and new methods are devised for raising the average standard of value of petroleum derivatives we are able to contemplate the approach of a day when none of the products of oil refining will be put to a base or inferior use, meaning a use which in one way or another involves a sacrifice of material or human values. This is the social-economic phase of conservation which is at least as important as the prevention of physical waste in production. An important step in that direction is the recent introduction of catalytic processes whereby most of the raw material is transformed into superior gasoline and a high grade gas oil, with very little residue of low-value products. If it becomes practical, as it very well may in course of time, to reach a stage of operation where no oil refinery will be turning out products of less value than a No. 2 gas oil this will result not only in conserving the value of the oil itself by converting it into more valuable products but also it will take it out of competition with other forms of fuel capable of performing the tasks to which it previously was directed. Thus the possibilities of this form of conservation are capable of diffusing economic and social benefits far beyond the confines of the oil industry alone.

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A Socony-Vacuum plant in Italy which includes a Houdry unit and has a catalytic charging capacity of 26,000 bbl. per day.

HOUDRY CATALYTIC Processes Opening New Era In Refining Operations

By Dr. O. W. Willcox

Installation of Units in Leading Refineries on Both Sides of Atlantic Provides Operating Results by Which Technical and Economic Value of Houdry Process Can Be Measured.

Eugene Houdry, president of the Houdry Process Corp.

In the separation of crude petroleum into elements of chief economic value, steps toward greater efficiency are made from year to year. Now and again a long stride forward is taken which affects the whole trend of development. Such a change has come through the application of catalysis which has opened a vast new field of usefulness through the experimentation of the past few years. Commercially the most striking progress in this particular field during the past year has come through the widespread introduction of Houdry catalytic processes in refining and treatment.

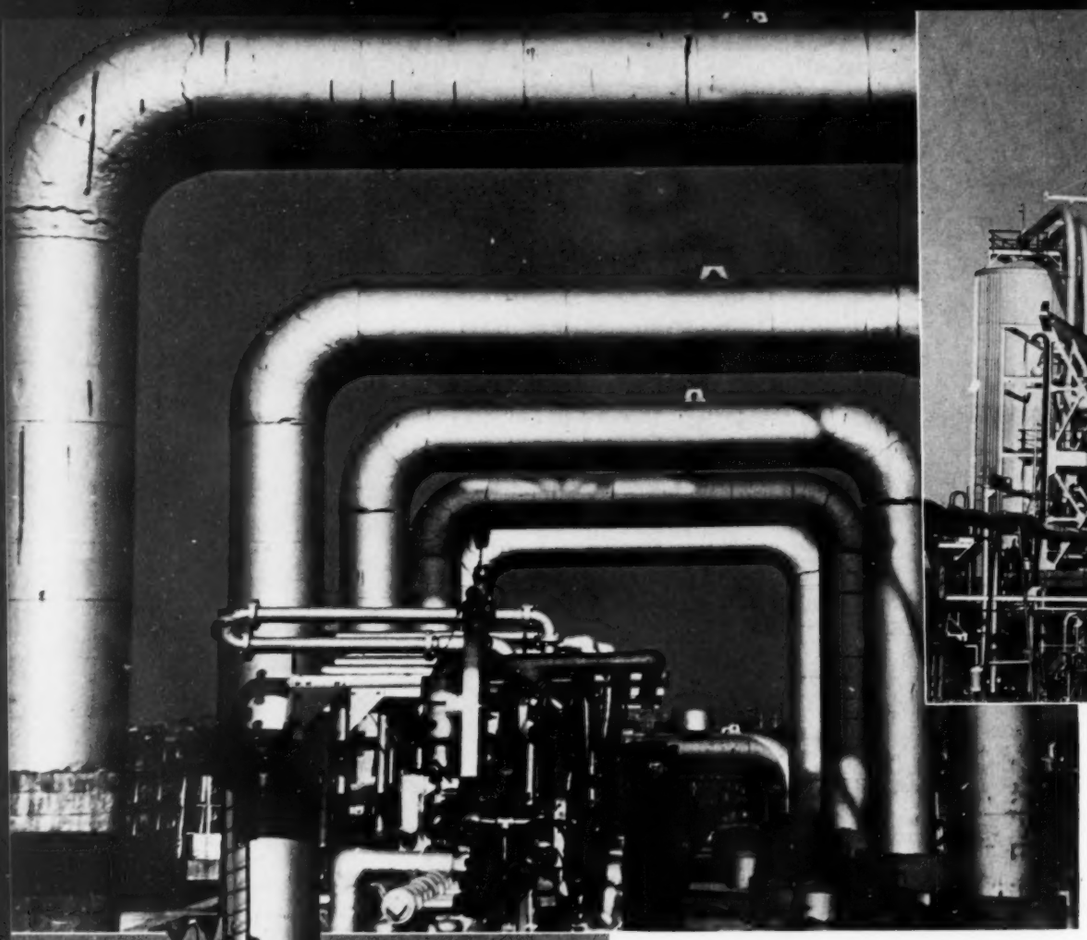
In two respects at least the group of Houdry processes has gained unusual distinction. No other process brought out in recent years has been the subject of such widespread interest and discussion. Probably no other has led to such a heavy capital investment in its operation within so short a time following its formal announcement. Certainly those most familiar with the processes have proved their faith by the expenditure of millions of dollars in the introduction of Houdry units into leading refineries of the United States and Europe. At the present time no less than fifteen of these units are in operation or under construction with a combined capacity of 221,675 bbl. daily. Without applying the hackneyed word revolutionary it appears that the Houdry processes are well on their way toward becoming a leading factor in the refining industry of today and tomorrow.

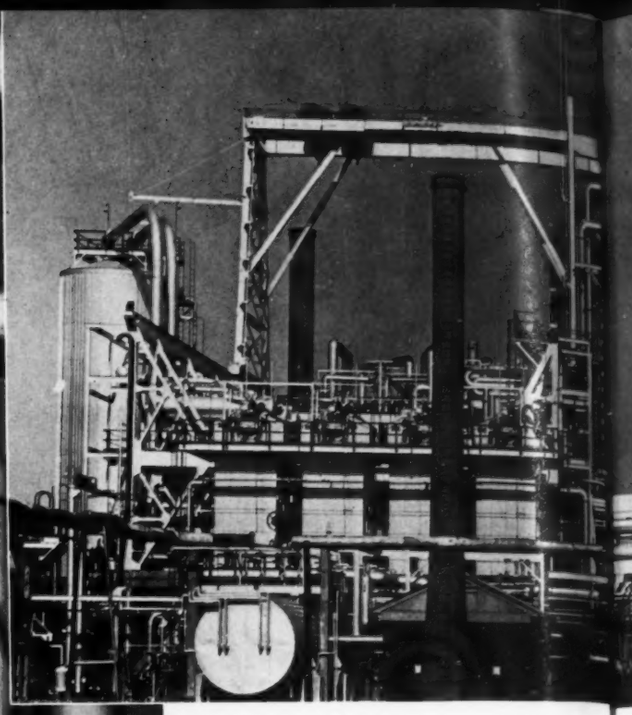
The Houdry process first came to general notice when Eugene J. Houdry and his associates presented a paper on the catalytic processing of hydrocarbons before the November (1938) meeting of the American Petroleum Institute. Previous to this announcement the process had gone through a long period of development, dating back to at least 1924.

As a result, the petroleum refining industry now has two well proven processes for converting heavy hydrocarbons into lighter and more valuable products—thermal cracking and catalytic cracking. In this article little effort will be made to draw an economic or a technical comparison between these two systems, but rather to indicate on the basis of available information, what the Houdry process is and to outline the forms of the process now available to the industry.

The Houdry processes are controlled by the Houdry Process Corporation, which is jointly owned by the Socony-Vacuum Oil Company, Inc., the Sun Oil Company, and Eugene J. Houdry and his associates. The licensing agents for the processes are E. B. Badger and Sons Company, who have built all the large modern plants excepting three that were built by Sun Oil Company's Engineering Division; Badger is also building the five plants now nearing completion.

In offering an explanation of what the Houdry Process is, an initial difficulty is presented by the impossibility (in the present state of scientific knowledge) of explaining the real natures of catalysts and the mechanism of catalytic reactions. The most that can or need be said in this connection is that a catalyst for hydrocarbon conversion is a substance which by its mere presence and without itself suffering any alteration, will induce changes in the nature of a hydrocarbon that would not occur if the catalyst were absent. Catalytic cracking or other molecular or chemical transformations of a crude petroleum product therefore means bringing the charg-



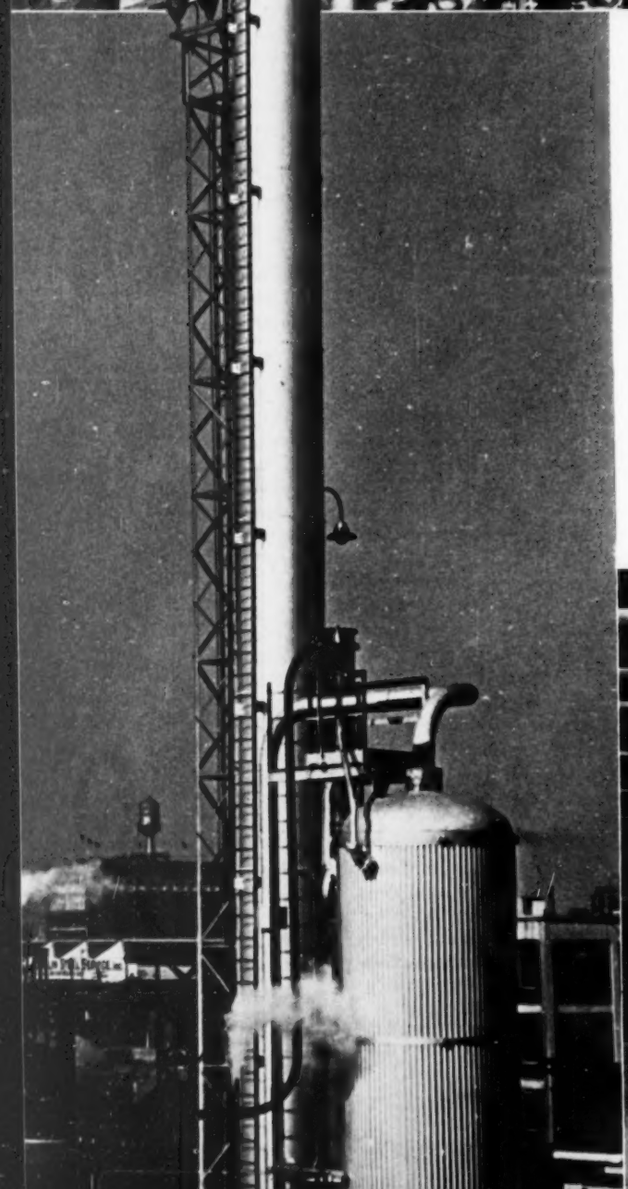


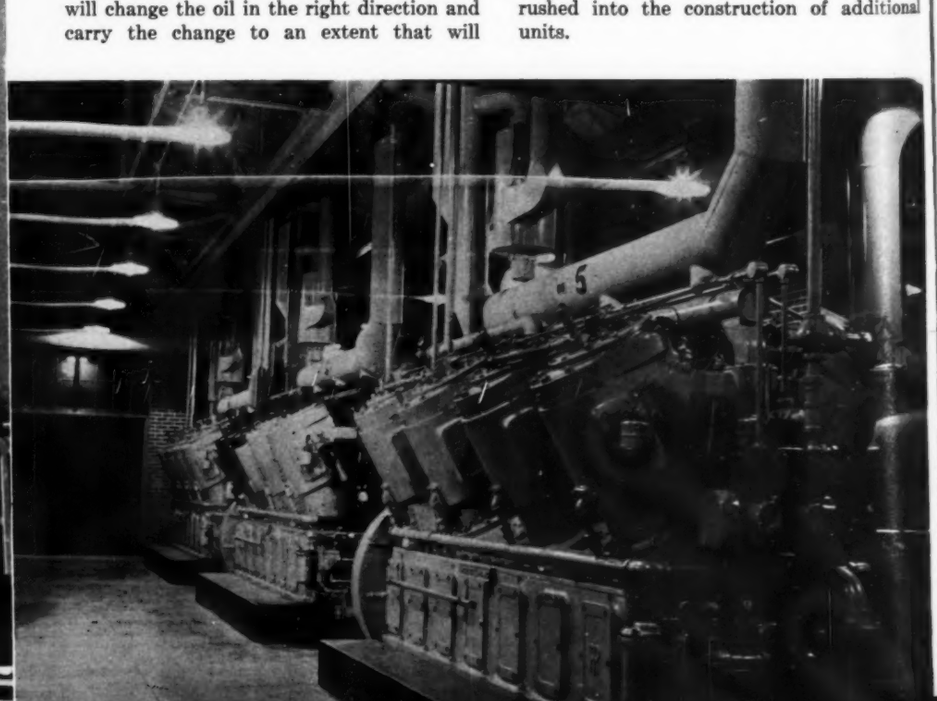
Left, salt and vapor transfer lines in some cases as big as 24 in. in diameter on a Houdry unit: Lower left, stabilizer unit in eastern plant of Socony-Vacuum: Lower center, charging pumps.

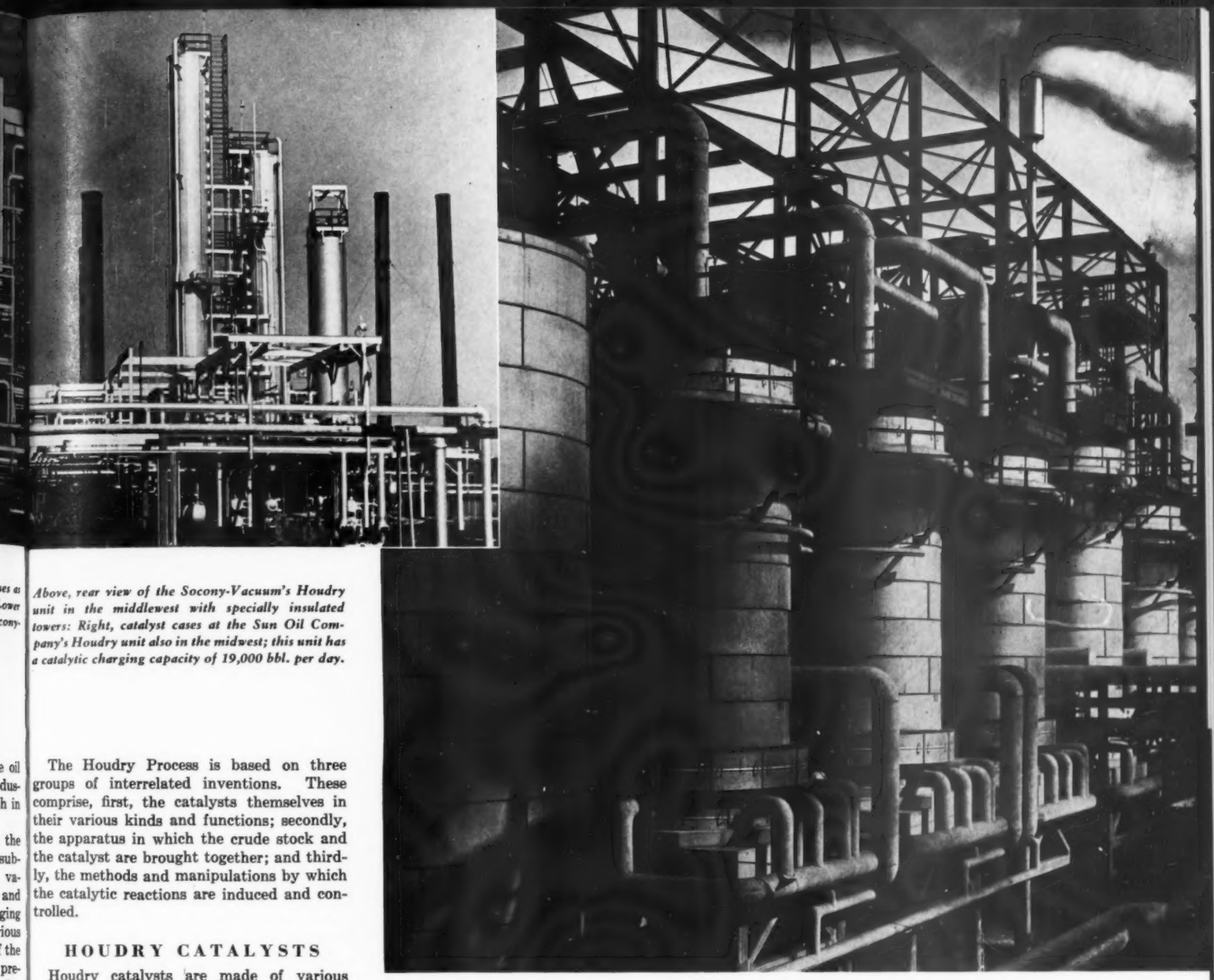
ing stock in contact with some substance that will induce reactions that change it into the desired products.

There is no absolute rule by which any substance may be selected for catalyzing other substances. Generally, whether or not any substance will act as a catalyzer can be found out only by experience. Hence, inventors in the field of catalysis proceed by the method of cut and try to develop empirical data. It is a fact that while a number of substances may be found to exert catalytic effects on oils, they will differ in their catalytic efficiencies; some will be capable of bringing about only a small degree of change in the oil. Some will be overactive and carry the change to excess and in wrong directions. Only after a long search is the inventor likely to find a catalyst that will change the oil in the right direction and carry the change to an extent that will warrant its introduction into large scale oil refining. After all, catalysts, like other industrial materials, have to prove their worth in terms of economic success.

Catalysts, as such, are no novelty in the petroleum industry. A large number of substances, including metals, chemicals of various sorts, and clay products have been and are now in use for catalytically changing petroleum and its derivatives in various directions. The rise and obvious success of the Houdry Process may be credited to the previously unmatched efficiency of the Houdry catalysts and its regeneration in use in the vital operations of cracking and reforming; they are now producing satisfactory results in plants costing, in the aggregate, some $35,000,000, and more millions are being rushed into the construction of additional units.







Above, rear view of the Socony-Vacuum's Houdry unit in the middlewest with specially insulated towers: Right, catalyst cases at the Sun Oil Company's Houdry unit also in the midwest; this unit has a catalytic charging capacity of 19,000 bbl. per day.

The Houdry Process is based on three groups of interrelated inventions. These comprise, first, the catalysts themselves in their various kinds and functions; secondly, the apparatus in which the crude stock and the catalyst are brought together; and thirdly, the methods and manipulations by which the catalytic reactions are induced and controlled.

HOUDRY CATALYSTS

Houdry catalysts are made of various materials, depending on the kind of operation for which the catalyst is intended. It does not appear that any one catalyst will answer all purposes of petroleum refining. As was remarked above, the task of an inventor in the field of catalysis is to select, by experiment, those materials that are operatively and economically superior. From that standpoint, the choice has fallen principally on certain natural or prepared clay and silicious materials, which may be summarily described as hydrated silicates of alumina in which the ration of silica to alumina is about four to one, with a minimum content of impurities such as calcium, magnesium and iron oxides. This is a preferred base material for catalysts that are to serve in Houdry catalytic cracking and transforming operations. The inherent catalytic action of this clay material may be reinforced or modified by including larger or smaller proportions of metals such as nickel, copper, manganese, etc., all depending on what has been found advisable in the inventor's cut and try experiments.

It is required of these catalysts that they have a fine porous structure (such as is often found in zeolitic materials); they must have the inherent catalytic property that enables them to crack and rearrange heavy hydrocarbon molecules; and they must be capable of being regenerated. This last requirement arises from the fact that catalytic cracking is a surface action, and the fact that the cracking operation produces a small residue of solid carbon that eventually clogs the active pores of the catalyst and impairs its catalytic activity. When this occurs it is necessary to remove the carbon deposit so that oil and catalyst may again come into intimate contact. Regeneration is most simply effected by burning off the carbon in a stream of air, and the catalyst must be of such a nature that it will withstand the resulting heat with out loss of its characteristic properties, which it must retain after many such regenerations.

Various other requirements are imposed on the catalyst; it must be sufficiently active and not over active; hence its composition and physical condition must be controlled to obtain a satisfactory activity. An important requirement is that it must be easily and quickly regenerated—too much time must not be consumed in burning off the carbon deposit; hence its chemical and physical properties must be tested from the standpoint of the regenerating operation.

A dry mixture of a natural or acid-treated clay and other materials having the required characteristics is ground to a fine powder, moistened to make a plastic mass, formed into small tubular or solid bodies or grains, (corresponding to about a 12-mesh screen), dried and baked at a suitable temperature and is then put into the catalyst cases.

The nature and preparation of Houdry catalysts are broadly described and claimed in numerous patents. As is usual in such matters, critical details of their compounding and processing are best known to the manufacturers, the Catalytic Development Co. (a subsidiary of the Houdry Process Corp.). This company has a factory at Marcus Hook, Pa., from which all catalytic masses used in Houdry units are supplied.

A normally prepared Houdry catalyst seems to have an indefinite life. Catalyst masses now in use have withstood thousands of regenerations without evidence of serious depreciation. The licensing agents make their economic estimates on the basis of replacing the catalyst every six months, although com-

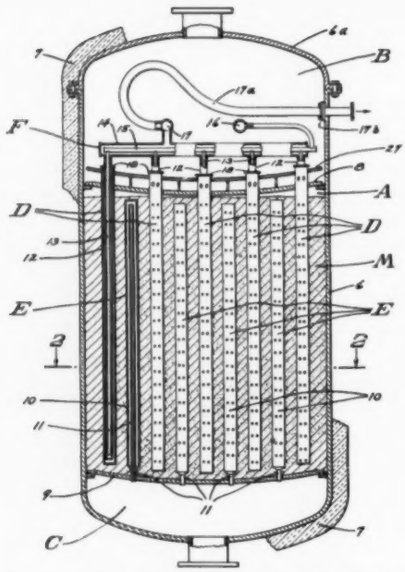


Figure 1: Vertical section of a Houdry catalytic case showing the inlet and outlet tubes for oil and air.

mercial results indicate this is conservative. It should be mentioned here that the catalyst cost for a plant catalytically cracking 15,000 barrels per day is of the order of $36,000.00.

CATALYST CASES

In bare outline, the Houdry Process of catalytic cracking consists merely in passing a stream of hot hydrocarbon vapor through a container filled with a porous mass of catalyst, collecting and separating the catalyzed products, and regenerating the catalyst when its activity has begun to fall off. Simple as it may sound, this operation presented mechanical and constructional difficulties that have called forth much inventive ingenuity. The circumstances to which a Houdry catalyst case must conform are exacting. For efficient cracking the oil vapors enter the case at a temperature of about 840 deg. F. This temperature would not be much of a complication if this same temperature were maintained all the time. But the on stream period of catalysis is short; carbon accumulates and must be burned off, and this must be done at a higher temperature (about 950 deg. F) by means of a current of hot air under pressure (about 50 lbs. per square inch). Hence there is a rapid alternation of higher and lower temperatures (at intervals sometimes less than five minutes) with accompanying expansions and contractions that would wreck an improperly designed case.

Even this was relatively a minor problem. A Houdry catalyst case is generally a large body which may be more than 30 ft. high and about 12 ft. in diameter; it contains a large mass of catalyst which in itself is a bad conductor of heat. When the "on stream" period is over and the regeneration operation takes place a large amount of heat must be removed in order that temperatures too high for the ensuing "on stream" period will not be reached. Hence the case must be equipped with means for effecting these temperature shifts and for keeping the temperatures of the two phases each within its proper limits. This is accomplished mainly by an ingenious system for circulating through the cases a heat absorbing and heat imparting medium, which in the modern plants is a mixture of fusible salts rather than a fluid like water or steam. The apparatus for circulating the oil, the regenerating air, and the heat-controlling medium is constructed with the one thought of effecting the most rapid possible exchange of heat.

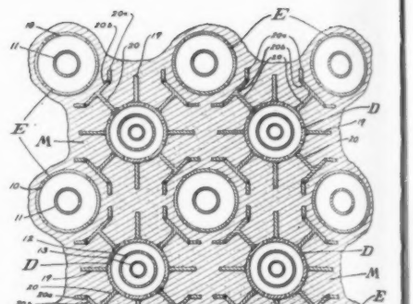


Figure 2: Horizontal section of a Houdry catalytic case showing the inner arrangement of the conducting tubes and fins.

Fig. 1, copied from one of the earlier Houdry patents (No. 2,078,949) will give a general idea of the interior of a catalyst case. The catalyst mass, M, is packed into spaces between the tubes D, through which the liquids pass for heat exchange. To promote rapid flow of heat to and from the mass of catalyst the tubes are provided with external heat-conducting fins, as shown in Fig. 2. These fins are so numerous and so spaced that no part of the catalyst mass is remote from a heat conducting metal surface, in some cases not more than one inch, for example.

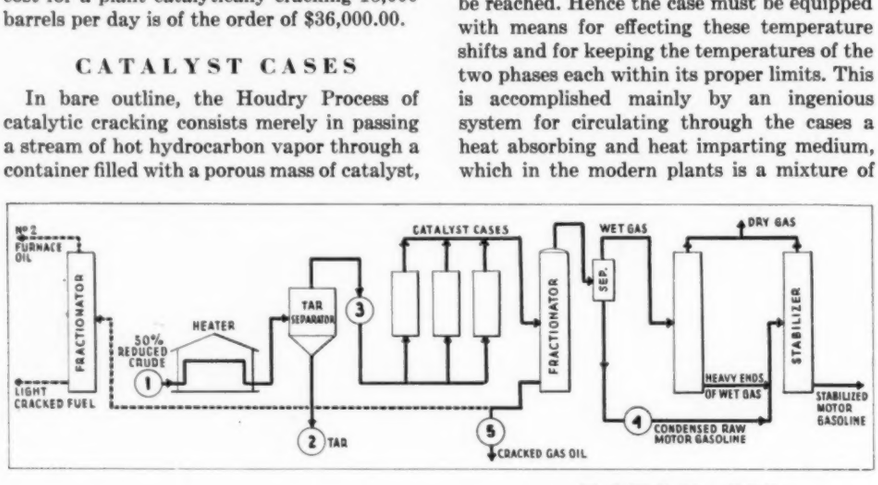


Figure 3: Flow diagram of Houdry process for production of motor gasoline and fuel oil.

TABLE III

Characteristics of Charging Stock and Product Yields

PHYSICAL CHARACTERISTICS	1 50% Reduced Crude	2 Tar	3 Charge to Catalyst	4 Cond. Raw Motor Gasoline	5 Cracked Gas Oil
Gravity °A.P.I.	16.8	12.3	17.2	53.4	17.8
Initial	531	.....	357	92	441
5%	568	.....	570	130	463
10	599	.....	580	150	486
20	632	.....	610	182	507
30	659	.....	625	202	524
40	671	.....	655	240	545
50	688	.....	670	268	563
60	698	.....	735	290	585
70	.....	.....	820	312	609
80	.....	.....	845	340	640
90	.....	.....	855	374	697
95	.....	.....	900	396	.....
E. P.	705+	.....	920	420	728
Recovery, %	68.0	.....	98.5	97.0	95.0
Residue, %	30.0	.....	.....	1.0	2.8
S. U. Vis./100°F.	739	.....	420	.....	42
S. U. Vis./160° F.	.....	1995	.....	.....	.....
S. U. Vis./210° F.	58	446	.....	.....	.....
Sulfur	.51	.60	.17	.05	.1
C. F. R. Octane—MM	.....	.....	.....	79.0	.....
R. V. P./100° F.	.....	.....	.....	7.4	.....
51 Dish Gum	.....	.....	.....	1	.....

YIELDS

	Percent Volume of Charge* to Catalyst
Stabilized Motor Gasoline	49.4
Cracked Gas Oil	51.0
No. 2 Furnace Oil	41.3
Light Cracked Fuel Oil	9.7
Dry Gas, Percent Weight	4.9
Coke, Percent Weight	4.4
C. F. R.-Stab. Cracked Gasoline	79.3

*Note: —Charge to case is the 50-94.6% cut of crude. The 94.6-100% cut of crude represents the tar removed by the tar separator.

Producing:—Motor Gasoline
Fuel Oil

Charge:—(To Plant) 50% reduced Mirando Crude.
(To Catalyst) 50-94.6% cut of Mirando Crude.

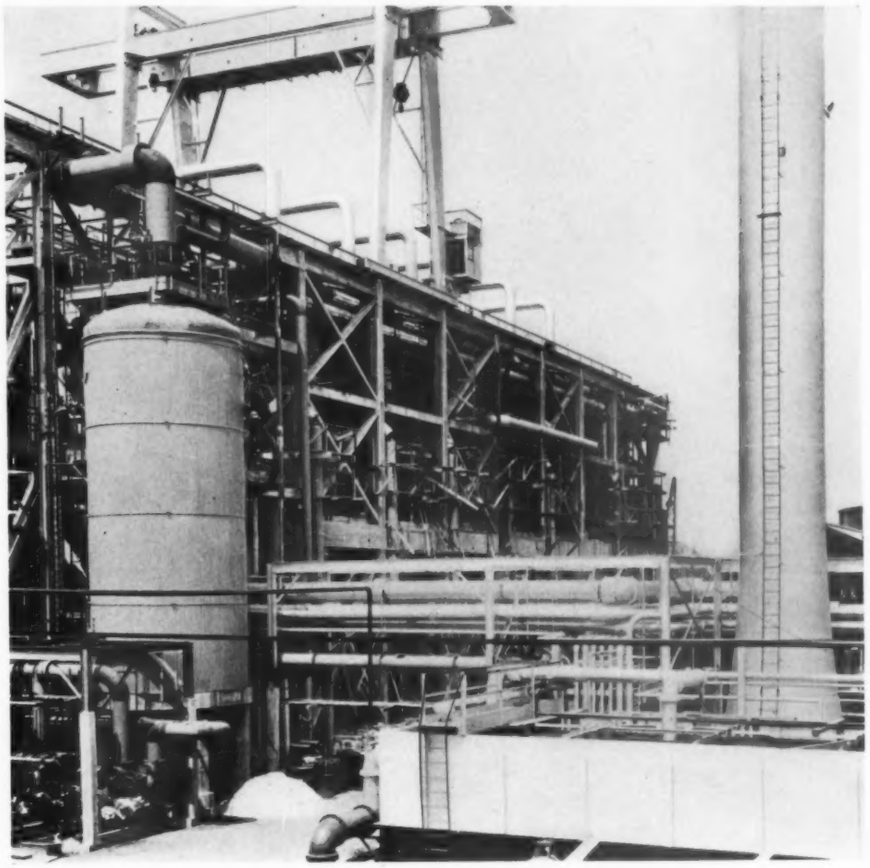
Auxiliary equipment outside the cases provides for recovering heat and power developed in the regeneration process.

The adequacy and engineering soundness of the constructional features of Houdry catalyst cases is attested by the reportedly small proportion of lost time in refinery operation that is attributable to the catalytic department. In the 16,700 bbl. Houdry unit at Magnolia No. 1 (Beaumont, Texas) this lost time amounted to less than 4.5 percent in the first four months of operation; it is stated that this record is being improved with experience, and that known causes of lost time are being eliminated in the newer plants. In any case, a shut-down of a Houdry cracking case is not quite as serious as it would be in a thermal cracking plant, as the catalyst case can easily be by-passed until the cause of the trouble has been rectified.

HOUDRY PROCESSES

A Houdry oil cracking or treating plant can be operated with a considerable number of independent variables under accurate control. These variables include pressure, temperature, rate of throughput, time of reaction, nature and form of the catalyst, ratio of charge to catalyst, and others. Any one or several of these variables can be changed in one direction or the opposite, the others being kept constant. With such a large number of independent variables under control, the number of possible operating combinations is great. In other words, the Houdry process is flexible in the sense that a given raw material can be processed to conform to fluctuating market conditions, supply of charging stock, or other external circumstances.

It would be impracticable, even in a much longer article than this one, to outline all the variants to which the Houdry process may be adapted by reason of its inherent flexibility. One example may be cited by way of illustration. The Magnolia Petroleum Co. required No. 2 fuel oil to meet their market requirements. This could not be obtained from their



One of Socony-Vacuum's New York state plants with a catalyst charging capacity of 10,000 bbl. per day.

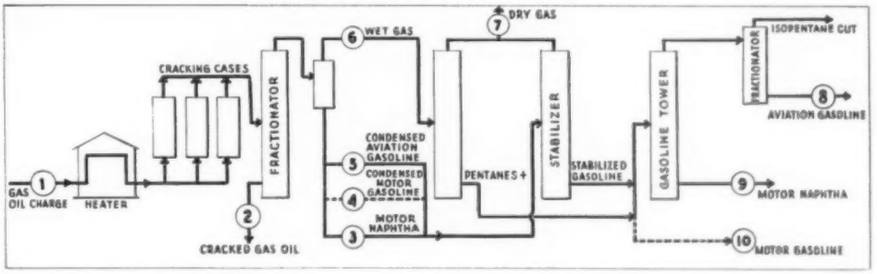


Figure 4: Flow diagram of Houdry process for producing heavy aviation gasoline and motor gasoline.

TABLE IV

Production of Heavy Aviation Gasoline and Motor Gasoline

A.S.T.M. DIST. OF STAB. AVIATION GASOLINE	7# R.V.P.	6.5# R.V.P.	6.0# R.V.P.
I B. P.	109	110	112
5%	127	134	136
10	136	140	146
20	147	150	157
30	161	162	169
40	176	176	184
50	195	192	200
60	214	210	218
70	234	232	236
80	257	256	260
90	290	286	290
95	314	306	310
E.P.	340	331	342
Percent Recovery	97	97	97
Residue	0.9	0.9	0.7
Percent off at 167° F.	36.0	35.6	30.3
Percent off at 293° F.	92.7	93.8	92.7

*Cracked Gas Oil Meets No. 2 Furnace Oil Specifications.

Physical Characteristics	1 Gas Oil Charge	Cond. Aviation Gasoline Less 10% Lt. Ends	4 Cond. Motor Gasoline	9 Motor Naphtha	2 *Cracked Gas Oil
Gravity, °A.P.I.	35.7	65.7	64.4	38.3	32.7
Initial B.P.	440	90	80	320	440
5%	464	111	96	330	460
10	484	119	110	334	468
20	498	140	132	340	477
30	510	158	157	345	486
40	522	180	189	350	495
50	534	195	215	356	505
60	550	218	230	362	518
70	572	240	283	370	533
80	600	267	314	380	558
90	646	297	362	400	600
95	704	327	.....	427	646
E. P.	724	358	392	452	692
Percent recovery	97	97	93	98	98
Residue	1.2	0.7	0.6	0.6	.....
Color	.....	30	.....	.....	.....
Gum-A.S.T.M.	.....	0	1	.....	.....
Ox.Bomb Stab.,Hrs	.....	10+	10+	.....	.....
R.V.P. at 100° F.	.....	11.8	16.2	.....	.....
Sulfur	0.18	0.01	0.01	0.01	.....
C.F.R.-Octane,MM	.....	80.6	80.9	.....	.....
S.U. Vis. at 100° F.	39	.....	.....	.....	35
Copper Strip	.....	Tarnish	Tarnish	.....	.....
Doctor	....	Sour	Sour	.....	.....

PERCENT VOL. STABILIZED YIELDS PRODUCING	Aviation Gasoline 7# R.V.P.	6.5# R.V.P.	6.35# R.V.P.	6# R.V.P.	Motor Gasoline 10# R.V.P.
PRODUCT					
Hvy. Aviation Gaso.	36.5	35.3	34.9	34.2	.....
Isopentane	.....	1.2	1.6	2.3	.....
Motor Naphtha	10.4	.....	.....	.....	50.2
Motor Gasoline	.....	.....	.....	.....	39.1
Cracked Gas Oil	39.1	.....	.....	.....	11.4
Gas (Percent Wt.)	13.7	.....	.....	.....	5.4
Cat. Deposit (% Wt.)	5.4	.....	.....	.....	.....
T+D/2	66.3	62.6	61.0	56.6	.....

Note—The aviation gasoline stabilized to 7# R.V.P. is butane free and contains all the pentanes and heavier fraction from both the condensed gasoline and wet gas. The 6.5# and 6.0# R.V.P. gasolines were actually prepared in the laboratory by fractionating off isopentane.

Producing:—Heavy Aviation Gasoline
Motor Gasoline
Charge:—E. Texas Gas Oil
440-724° F.

Motor installation in one of the new Houdry units.

thermal units which were producing a yield of 44.4 percent of gasoline from the refractory Mirando (South Texas) crude, along with 46.3 percent of tar and 9.3 percent gas and loss, and this result required a recycle ratio of six to one. The answer to their problem was a 16,700 bbl. Houdry catalytic cracking unit with which, by an appropriate set of operating conditions, the production of gasoline was purposely made a secondary consideration and production of No. 2 gas oil the primary object. Under that set-up and from substantially the same charging stock, the unit is delivering 33.3 percent of 82 octane-number gasoline (which needs only sweetening), 32.6 percent of No. 2 fuel oil, 17.4 percent of heavy gas oil, 12.7 percent of tar and 4.0 percent of gas and loss on a once through basis. The yield of No. 2 gas oil from this unit was later increased to 44 percent by altering the distillation to make a better separation of the heavy gas oil. This readjustment of the quantities of the various products as practised at Magnolia is well within the limits of prevailing economic circumstances, and it is stated that under such a regime the installation will not be long in paying out the investment. With similar regard to economic considerations other Houdry plants have been designed and built to produce relatively larger yields of gasoline (up to around 45 percent of charge to catalyst on a once through basis) with correspondingly smaller amounts of heavier products. However, by appropriate change in operating conditions and with little or no material alteration of equipment, any of these plants may change from high to low gasoline yield, or vice versa, as dictated by circumstances.

The recent expansion of the market for domestic heating oil and the historic slump in heavy fuel oil consumption lend emphasis to the desirability of flexibility in refinery production. Of similar import is the impending expansion of the demand for gasoline of aviation quality.

It is understood that the licensing agents whose reputation in the field of refinery engineering is well known, are offering to build complete Houdry units for any of the well established variants of the Houdry processes (see further on), to supply competent operators, and to guarantee certain minimum results.

In passing, it may be noted that among other reasons it was mostly this control over the ratios of the products, and the adaptability of the process to any kind of charging stock that prompted the Socony-Vacuum Oil Co., and the Sun Oil Co., to invest heavily in the development of the Houdry processes. In an address before a French oil technologists' association Mr. Houdry relates that he was extremely gratified by the success of a 600-bbl. unit at Paulsboro, N. J., which produced in 1933 an 80-octane-number gasoline with a yield of 80 percent from Pennsylvania gas oil in several passes. But, to his great surprise, the big American oil men told him that while those results were certainly interesting, they did not amount to a solution of the main economic problem then existing, which was the transformation of residues. Acting on this hint the development of the process was successfully extended to allow of extracting previously inaccessible values from a nearly worthless by-product. This was first accomplished (1935) in a 600-bbl. unit at Marcus Hook, which satisfactorily treated a 35 percent East Texas residue over an operating period of 1½ years. Thereupon the Houdry Process Corp. was given orders for the construction of eleven large units involving a capital investment of $35,000,000, two-thirds by Socony and one-third by Sun Oil.

At the present time the Houdry plants listed in Table I are in operation or in process of construction.

It is understood that negotiations for building three or four other large units are in progress.

TABLE I

Capacities of Houdry Units in Operation and Under Construction

Company	Location	Type	Charging Stock	Capacity Charge Stock	Bbls./Day Case Charge
IN OPERATION:					
Socony-Vacuum Oil Co.	Paulsboro, N. J.	Cracking	Gas Oil	2,000	2,000
Sun Oil Co.	Marcus Hook, Pa.	Cracking	Reduced Crude	15,000	12,000
Raff. di Napoli	Naples, Italy	Cracking-V. Treating	Gas Oil	2,600	2,600
Magnolia Petroleum Co. No. 1	Beaumont, Texas	Cracking	Crude	16,700	15,000
Sun Oil Co.	Marcus Hook, Pa.	Cracking-V. Treating	Crude	28,000	19,000
Socony-Vacuum Oil Co.	Detroit, Mich.	Cracking	Crude	19,400	10,500
Socony-Vacuum Oil Co.	Brooklyn, N. Y.	Cracking	Mixed	12,000	10,000
Sun Oil Co.	Toledo, Ohio	Cracking-V. Treating	Crude	28,000	19,000
Magnolia Petroleum Co., No. 2	Beaumont, Texas	Cracking	Mixed	17,800	15,000
Socony-Vacuum Oil Co.	Buffalo, N. Y.	Cracking	Crude-Gas Oil	16,000	10,000
UNDER CONSTRUCTION:					
Socony-Vacuum Oil Co.	East St. Louis, Ill.	Cracking	Crude	18,400	10,000
Socony-Vacuum Oil Co.	Augusta, Kansas	Cracking	Crude	23,500	10,000
Socony-Vacuum Oil Co.	Paulsboro, N. J.	Cracking	Crude-Gas Oil	12,700	10,000
Raff. Vacuum Oil, SAF	Gravenchon, France	Cracking	Gas Oil or	2,200	2,200
			or Naphtha	3,200	3,200
Raff. de Berre	Berre l'Etang, Fr.	Cracking	Gas Oil or	4,535	4,535
			Reduced Crude	6,375	5,500
			Total	221,675	153,860

General night view of the Houdry unit in a plant of the Sun Oil Co. The catalyst charges 19,000 bbl. per day.

OPERATIONS CONTEMPLATED

At the November (1938) meeting of the American Petroleum Institute it was announced that the processes available under the more than 100 Houdry patents and their developments are as follows:

1. Catalytic cracking of a crude or any distillate fraction or residuum thereof, excepting straight-run gasoline, for the production of gasoline, gas oils, furnace oils, with or without the production of tar or heavy liquid products.

2. Catalytic viscosity breaking in liquid phase by which residues or tars may be reduced in viscosity to meet fuel specifications, without substantial production of gasoline.

3. (a) Catalytic treatment of gasoline from catalytic or thermal cracking.

(b) Liquid-phase catalytic treatment of aviation gasoline from catalytic cracking.

4. Catalytic de-sulfurization of gases from cracking or topping operations.

5. Catalytic polymerization in liquid phase of butenes.

6. Production of light-gravity gas oils for furnace-oil requirements or diesel oils by catalytic cracking, charging heavier - gravity gas oils or residuums.

Of the processes in the above list by far the most important at the present time is the catalytic cracking of crude oils and fractions or residues obtained therefrom. Chief interest now centers mainly on four principal set-ups which are outlined farther on in this article.

PRODUCTS

As was remarked previously, the products of Houdry operations are variable almost at will over a considerable range of quantity and quality.

It has been stated that the Houdry cracking operation has among others three points that are especially notable from the technical and economic standpoints, namely:

(a) Consistently high yields of gasoline from *any* crude oil on a once-through operation.

(b) Unusually high octane rating of the gasoline produced.

(c) High percentage of liquid recovery, amounting in many if not most cases to practically complete volumetric conversion of the heavy components of the charge into gasoline and gas oils.

Results show that, whatever the nature of the crude oil or its topped residue, the amount of gasoline produced is sensibly about the same, being around 44 or 46 percent of the charge to catalyst. In special cases, as when charging the entire crude of a non-refractory oil the once-through yield of gasoline may exceed 60 percent. At the same time there is a fair yield of good catalytic gas oil, and what may be regarded as a moderate production of dry gas, carbon and heavy furnace oil, if any.

The above refers to the production from one pass. Catalytically produced gas oils can be recycled to the cracking cases, and while the yield from each successive cycle is progressively smaller, it has generally turned out to be higher, pass by pass, than is usually obtained in a thermal cracking unit.

The relations here are shown in Table II. Concerning the catalytically cracked gas oils it has been noted that they make excellent charging stocks for thermal cracking units. In such a case it has been found that the gasoline produced will have a somewhat higher octane rating than gasoline obtained from the thermal cracking of virgin gas oils from the same crude.

TABLE II

Gasoline Yields in Houdry Process

Stock	Charge Percent of Virgin Stock	Cumulative Yield of Gasoline Percent by Volume
Mid-Continent gas oil 37.8 deg. A. P. I.—		
Virgin stock	100.0	44.7
Second pass	53.0	59.5
Third pass	33.7	67.2
Residual gas oil	32.4	....
Mid-Continent 17.5 percent bottoms—		
Virgin stock	100.0	47.7
Second pass	46.1	54.0
Third pass	33.8	62.9
Residual gas oil	26.0	....
38-92 percent Cut E. Texas crude—		
Virgin stock	100.0	45.5
Second pass	53.9	62.3
Residual gas oil	32.7	....

The figures in Table II are not necessarily limiting. In some cases, as with Pennsylvania gas oils, the cumulative yield of gasoline may attain 80 percent or more.

Laboratory data indicates that the liquid recovery, in percent by volume of the charge to catalyst, runs as high as 99 percent and in some cases more than 100 percent. That is to say, for every barrel of crude oil or topped crude that is fed to the catalyst cases, there is obtained practically one barrel of salable liquid products. While there is thus little or no loss on a gallonage basis it is true that appreciable losses have occurred in the form of dry cracked gas that is disposed of as fuel, and a further loss represented by the carbon deposited on the catalyst. Nevertheless, the liquid output practically equals or even exceeds the liquid input, because the cracking operation breaks down the heavy molecules into lighter ones. The total loss of gas and carbon may be of the order of 10 percent, but since liquids of high A. P. I. gravity take the

Figure 5: Flow diagram of Houdry process for producing aviation gasoline (7 lb. R. V. P.) and motor gasoline (10 lb. R. V. P.)

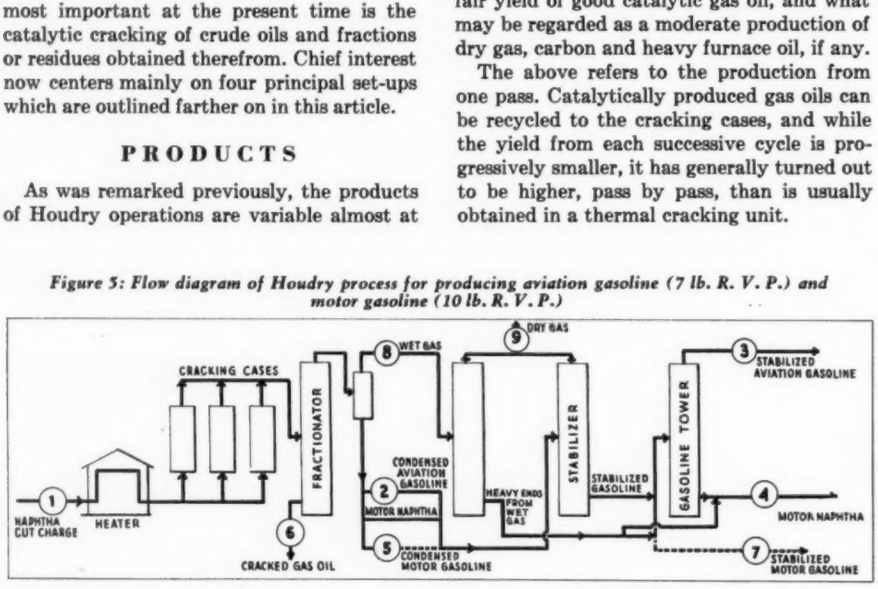


TABLE V

Aviation Gasoline 7 lb. R. V. P. and Motor Gasoline 10 lb. R. V. P.

PHYSICAL CHARACTERISTICS	1 Naphtha Cut, Charge to Catalyst	2 Cond. Aviation Gasoline (less 7% light ends)	3 Stabilized Aviation Gasoline	4 Motor Naphtha	5 Cond. Motor Gasoline (less 3.3% light ends)	6 Cracked Gas Oil
Gravity, °A.P.I.	46.8	64.1*	60.1	39.5	57.8	25.2
Initial	154	96	104	311	104	412
5%	206	132	130	317	140	424
10	224	146	144	322	160	430
20	252	168	166	327	194	436
30	278	186	184	331	216	440
40	305	202	199	336	236	446
50	334	215	214	340	256	454
60	362	226	226	346	275	464
70	388	240	242	353	296	476
80	410	254	256	361	302	498
90	435	280	276	380	352	544
95	448	306	300	391	384	620
E. P.	464	322	328	416	392	694
Percent Recovery	98	97	98	98	97	98
Residue	1.0	0.8	0.8	0.6	1.2	1.6
Percent Dist./167° F.	.....	.....	21.7	.....	.....	.....
T+D/2	.....	.....	59.1	.....	.....	.....
Color	18	30	.....	.....	30	.....
Gum-A.S.T.M.	.....	0	.....	.....	0	.....
Ox Bomb Stab. Hrs.	10+	10+	.....	.....	.....	.....
R.V.P./100° F.	2.4	.....	7.0	0.1	.....	.....
Sulfur	0.03	0.01	.....	0.01	0.01	0.07
C.F.R. Octane	57.2	78.0	77.6	70.9	76.5	.....
Doctor	Sour	Sour	.....	.....	Sour	.....
Copper Strip	O.K.	O.K.	.....	.....	Tarnish	.....

*Totally condensed.

STABILIZED YIELDS (Percent Volume of Charge)

PRODUCING AVIATION GASOLINE (7 lb. R.V.P.)

Aviation Gasoline	58.75
Motor Naphtha	21.40
Cracked Gas Oil	9.1
Dry Gas, Fuel Oil Equivalent, Percent	*12.14
Cat. Deposit, Fuel Oil Equivalent,%	1.71

PRODUCING MOTOR GASOLINE (10# R.V.P.)

Motor Gasoline	83.42
Cracked Gas Oil	9.1
Dry Gas, Fuel Oil Equivalent, %	8.22
Cat. Deposit, Fuel Oil Equivalent, %	1.71

*Based on Percent Weight Dry Gas = 13.08 Percent after Stabilizing Aviation Gasoline only.

Producing:—Aviation Gasoline (7# R.V.P.)
Motor Gasoline (10# R.V.P.)

Charge:—(For Reforming) Int. 30.9 Percent Naphtha Cut of Heavy Grade B Crude (29.7° A.P.I.)

place of the original liquids of low A. P. I. gravity, there is no apparent shrinkage in volume.

QUALITY

The quality of Houdry cracked and transformed products is naturally determined or at least limited by the character of the original charging stock, but, without undertaking here a detailed comparison between Houdry cracked and thermally cracked petroleum products it is evident, from figures that have been given out, that the quality of Houdry products represents a distinct advance. In certain particulars and as regards particular original stocks the improvement is truly remarkable. Disregarding spectacular elements, the data contained in Tables III, IV, V and VI, obtained through E. B. Badger and Sons Co., the licensing agents, represent what may be expected from four types of Houdry installations. The figures in these tables are considered as approximative minima, and have been made a basis for calculating prospective installations. It is stated that the performance of completed plants has generally exceeded the promise.

A notable feature of Houdry gasoline is its relatively high octane number in the clear grade, normally around 78 to 82. An interesting circumstance is a wide spread between the octane numbers of a stabilized Houdry gasoline as determined by the motor method (around 79) and the 1939 Research method (around 92) without tetraethyl lead. This gasoline also has a good lead susceptibility; with 3 ml. of T E L the octane-number is of the order of 87 (motor method) or 98 (Research 1939). This is noteworthy in view of the fact that thermally cracked gasoline shows a narrower spread between the octane numbers by the two methods. The upshot is that Houdry motor gasoline has a large blending value, which in certain commercial variants of the process may attain 136. This obviously means that when blending for a given octane number (Research method), less Houdry gasoline is required or, alternatively, less tetraethyl lead need be added to blends compounded of equal parts of Houdry and thermally cracked gasoline.

The gas oil is of a quality suitable for improving the grade of heavy fuel oil, and for blending off whatever tar is separated from the heated oil vapors on their way to the catalyst cases. When used as thermal-cracking stock it is generally found that it gives the same results as virgin gas oil of the same physical characteristics.

What is regarded as an especially valuable characteristic of the Houdry catalytic cracking process is its ability to produce aviation gasoline direct from the original charging stock. In the first place it yields an untreated catalytic gasoline with a low gum content, a long induction period and a low sulfur content. When this product is separated at an end point around 300 deg. F. and given a further catalytic treatment it will have an A.S.T.M. octane number around 78 in the clear grade, which with 1.8, 3, or 4 ml. of tetraethyl lead may be stepped up to 87, 90, 92 octane without recourse to blending agents. In volatility, acid heat number, etc., it will meet aviation specifications. One of the outstanding characteristics of Houdry gasoline is that the naphtha cut will have, in most cases, the same octane number as the aviation cut and motor gasoline.

From this aviation grade it is possible to make 100 octane number gasoline by addition of blending agents such as isooctane, isopropyl ether, or other synthetic anti-knock materials, together with tetraethyl lead. An interesting point in this connection is that in compound-

Figure 6: Flow diagram of Houdry catalytic process for treating raw gasoline.

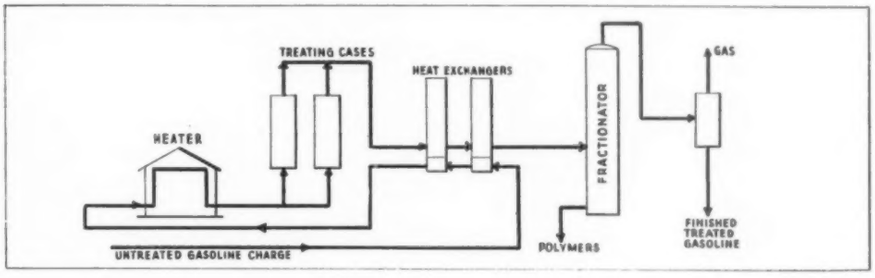


TABLE VI

Houdry Catalytic Treating Process Results on Various Catalytic Gasolines and Blends

CRUDE	EAST TEXAS				WEST TEXAS				GRADE "B"		Mt. PLEASANT		MIRANDO	
	Houdry Cracked Gasoline from 62% Bottoms of Crude		Mixture—Catalytic Gasoline Str. Run Gasoline Thermally Reformed Gasoline in Proportions Produced from Crude		Houdry Cracked Gasoline from 68.5% Bottoms of Crude		Mixture—Catalytic Gasoline Str. Run Gasoline Thermally Reformed Gasoline in Proportions Produced from Crude		Houdry Cracked Gasoline from 75.1% Bottoms of Crude		Houdry Cracked Gasoline from 62% Bottoms of Crude		Houdry Cracked Gasoline	
TREATING YIELD														
Gas, Percent Wgt. of Chg.	0.4		0.8		0.30		0.3		0.3		0.4		0.5	
Coke, Percent Wgt. of Chg.	0.2		.....		0.40		0.3		0.3		0.3		0.4	
Polymers—Percent Vol. Chg.	.....		.....		.....		0.1		0.1		.....		0.1	
Treated Gasoline—Percent Vol. Chg.	99.2 Est.		98.8 Est.		99.0 Est.		99.3		99.3		33.1 Est.		99.0	
INSPECTION OF GASOLINE	**Raw**	**Treated**	**Raw**	**Treated**	**Raw**	**Treated**	**Raw**	**Treated**	**Raw**	**Treated**	**Raw**	**Treated**	**Raw**	**Treated**
Gravity °A.P.I.	60.6	59.6	59.1	57.3	56.5	55.0	58.5	59.6	54.5	53.5	59.4	58.8	50.3	50.5
Initial	94	100	90	104	84	102	94	100	112	104	92	104	119	106
5%	122	122	128	136	112	138	132	142	146	140	121	130	151	146
10	138	144	142	154	136	158	148	157	162	160	139	146	170	188
20	162	168	172	180	170	190	175	178	188	186	166	171	201	200
30	186	192	195	202	202	216	198	194	212	210	191	199	228	232
40	208	214	218	225	230	242	214	208	236	240	216	222	263	262
50	232	238	238	248	256	276	238	221	260	264	244	252	289	289
60	258	258	270	274	286	297	256	234	284	292	259	276	312	314
70	280	290	290	296	315	326	277	256	310	318	296	301	334	338
80	308	316	327	336	346	350	297	282	336	342	311	330	352	354
90	338	348	370	372	380	380	328	335	360	372	346	357	373	374
95	360	374	400	396	412	....	352	368	378	392	368	376	386	390
E. P.	382	392	417	410	422	400	371	395	398	412	394	403	404	405
Percent Recovery	97	97	97	97	96	95	97	98	98	97	97	97	97	97
Residue	1.2	1.1	1.0	1.0	0.4	1.2	1.4	0.9	1.2	1.1	1.0	1.4	0.8	0.8
S.I. Dish Gum	0	0	2	1	1	1	1	1	2	0	0	1	5 (oily res)	1
C.U. Dish Gum	3	3	15	4	13	5	11	6	13	1	1	1	27 (oily res)	10
Sulfur	0.02	0.01	0.04	0.02	0.15	0.12	0.11	0.06	0.05	0.07	0.01	0.01	0.03	0.04
Doctor	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour	Sweet	Sour	Swe-t
Copper Strip	O.K.	O.K.	Tarn.	O.K.	Tarn.	O.K.	Tarn.	O.K.	O.K.	O.K.	O.K.	O.K.	O.K.	O.K.
Color	21	30	18	30	14	28	29	30	21	24	22+	30	29	30
After 4 Hrs. Slab Test	....	30	....	....	....	....	....	30	....	....	....	29+	....	30
After 8 Hrs. Slab Test	....	30	....	....	....	....	....	30	....	....	....	27	....	30

ing 100 octane number gasoline the usual amount of expensive blending material, such as isooctane, may be reduced by half. In view of the limited supply of isooctane and the difficulty of procuring it, this method of making isooctane go further represents a conservation of natural resources.

ECONOMICS

Any discussion of the economics of the Houdry catalytic cracking process would involve a comparison with the economics of the thermal cracking process; such a comparison involves too many considerations to be brought within the scope of this article. There does not appear to be any doubt, however, concerning the ability of Houdry cracking to compete with thermal cracking under the existing set of economic circumstances. The simple fact that millions of dollars have been invested in numerous large operating plants and that new Houdry plants are being built or projected is conclusive evidence that the investment is considered profitable. According to a public statement by an official of the Sun Oil Company, a Houdry unit will pay out all plant and royalty charges in less than three years. This pay-out is based on East Texas crude at $1.44 per bbl. at New York, gasoline at 5.88 cents a gallon, heavy fuel oil at 77 cents a bbl. and gas oil at $1.20 per bbl. The plant operations are predicated on running a 50 percent bottom of East Texas crude through the unit. It has further been stated that running on gas oil will pay out sooner than where reduced crude is run at higher throughput rates and consequent lower capital charges per barrel.

It has been estimated by petroleum engineers that thermal cracking costs 12 to 14 cents per barrel of throughput and an impression has gone abroad that the corresponding costs for catalytic cracking is 10 to 12 cents.

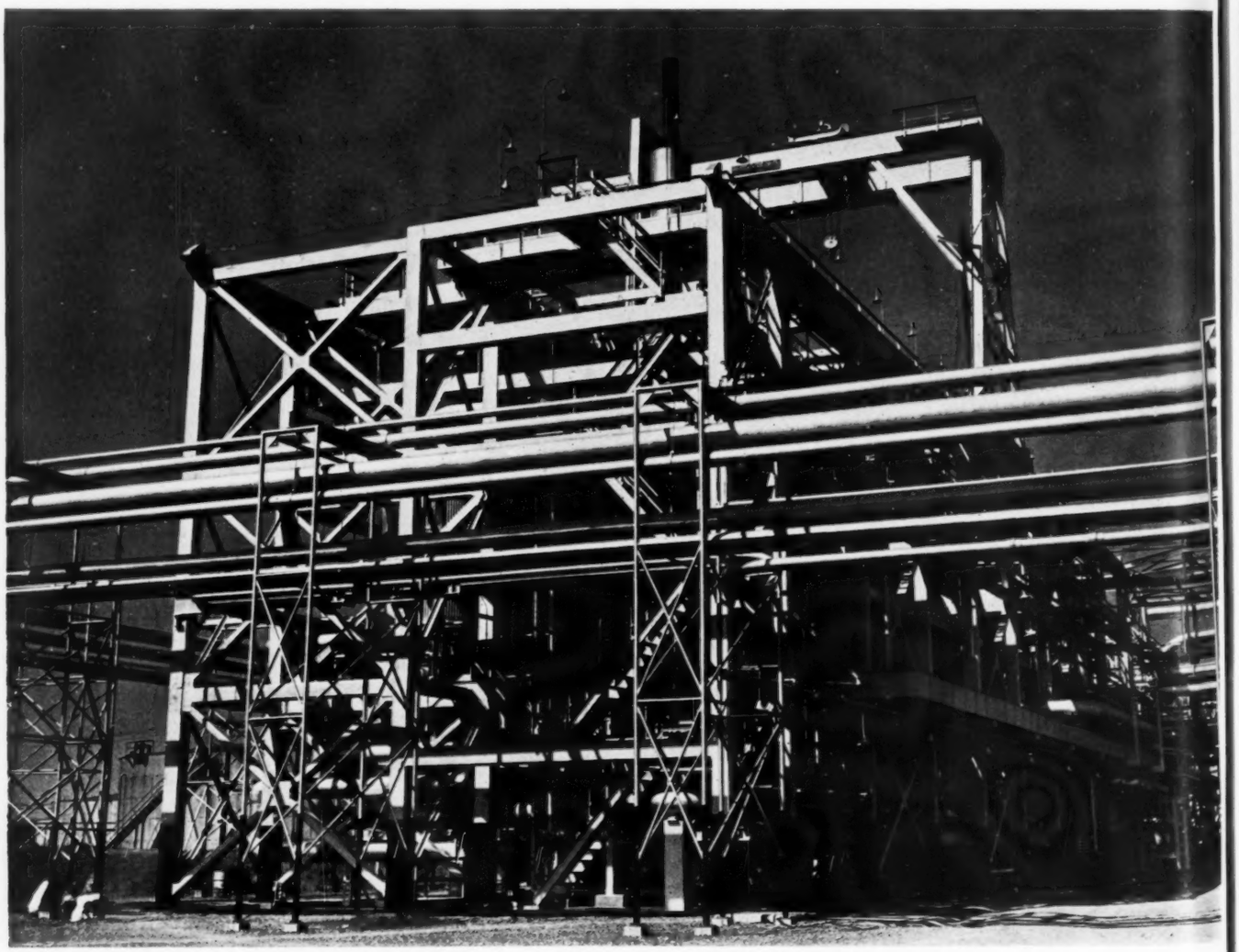
At the Atlantic City Meeting of the National Petroleum Association in the discussion following papers on catalytic cracking, an official of the Sun Oil Company quoted the following figures pertaining to catalytic cracking based on actual operations:

"For a plant charging 38,150 bbl. per day of East Texas Crude of which 13,300 bbl. is charged to the catalyst cases, for the production of 43 percent of gasoline based on case charge, the daily cost amounted to $1,391.10. This figure includes the following unit prices:

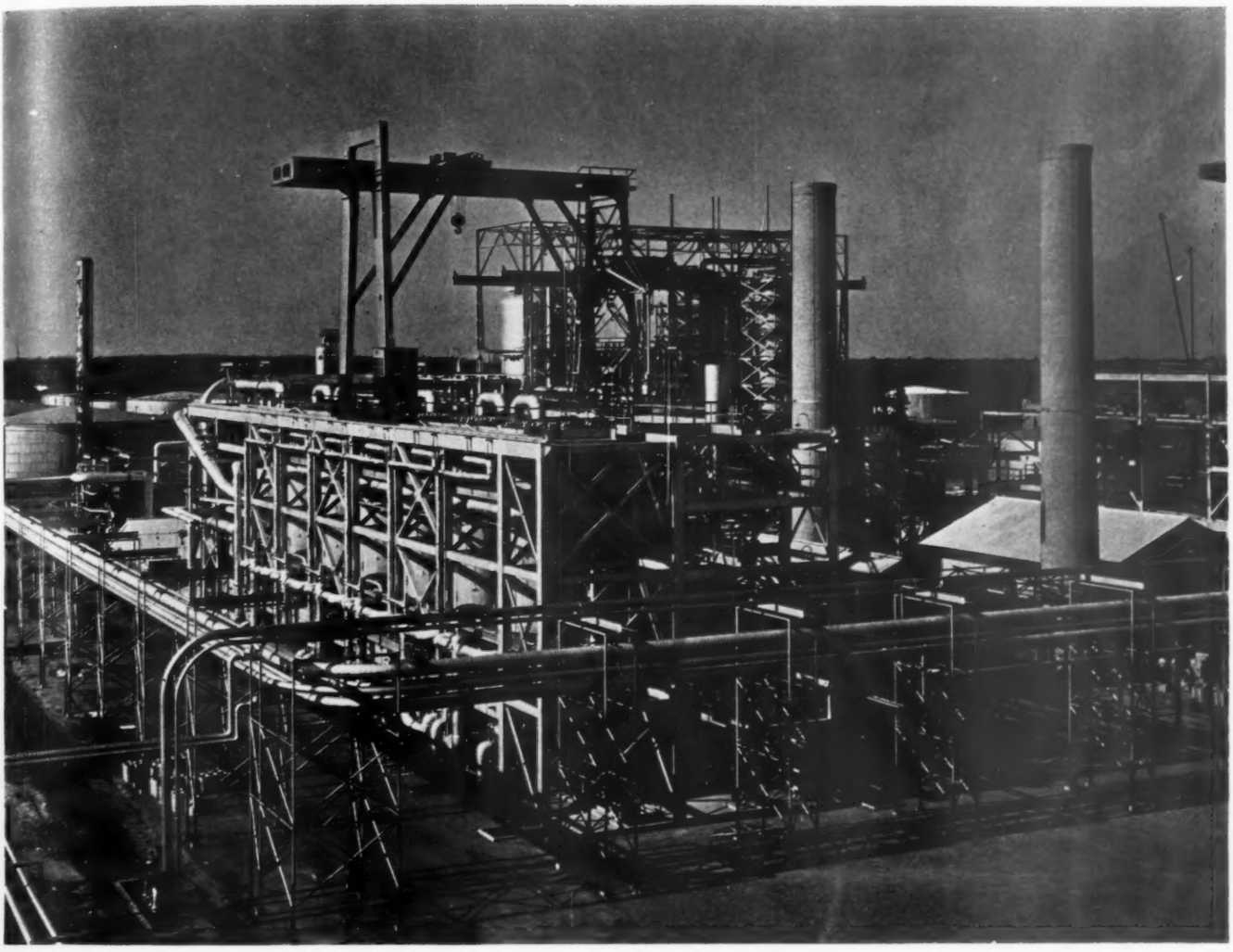
Fuel at 13.1c. per million B. T. U.'s.
Steam at 25c. per thousand pounds.
Cooling Water at $6.00 per million gallons.
Power at .6c. per KWH.
Treated Water at 25c. per thousand gallons.
Catalyst cost $272 per day.
Operating labor at $1.00 an hour.

"Against these costs $1,391.00 per day, the plant is credited with steam, power and heat recovery over and above that required to operate the plant to the extent of $1,007 per day, leaving a net cost of utilities and labor of $384.10 per day or approximately 1c. per barrel of crude oil charged. This is equivalent to 2.965 cents per barrel charged to catalyst. When overhead is charged in, the total cost might be 6c. or 8c. per barrel."

Still quoting public statements by the Sun Oil official above referred to, it will be realized also that the real value of catalytic cracking consists mainly in the appreciation of value which the process imparts to the final salable products. In that respect the comparison of catalytic with thermal cracking



Magnolia Petroleum Company's Houdry unit in Texas. This plant has a crude charging capacity of 16,700 bbl. per day and a catalytic charging capacity of 15,000 bbl. per day.



A general view of the Houdry unit in a western plant of Magnolia Petroleum Company.

reduces to this: The final products of thermal cracking are gasoline, gas oil, fuel oil, coke and gas; in catalytic cracking the final products are gasoline, gas oil and small quantities of gas. In the latter process the nearly worthless by-products of thermal cracking—fuel oil, coke and excessive quantities of gas—do not appear. A decidedly larger proportion of the raw material is transformed into the two products which have the highest commercial value, and the quality or grade of these two products of catalytic cracking is higher than that of corresponding products from thermal cracking.

On the other hand, it appears that under existing conditions the Houdry process is more attractive for large than for small installations. It is agreed that the investment cost per barrel of throughput in small units is high, but it has been suggested that it is no higher, on a percentage bases, than between large and small thermal cracking units. A small refiner may obtain a quick improvement in octane number by making use of a catalytic reformer with which to process his thermally cracked gasoline, but it is stated that his pay-out will be quicker if the catalytic cracking unit is built.

Although the Houdry Process Corporation has so far specialized in big units for the United States, it is now building some small units of 1,600 to 4,500 bbl. capacity in France, where cost and price conditions are somewhat different. It is understood that work is now in progress that may improve the economics of small Houdry installations.

Some refiners who have been considering the Houdry process have recorded the opinion that the process is particularly suited for new installations. An existing up to date thermal cracking plant may still get by, at least for some time to come. Not enough Houdry installations are yet in operation to capture the market for high quality products, and meanwhile thermal cracking may find means to strengthen itself.

COMMERCIAL VARIANTS

Among the possible uses to which the Houdry inventions may be put chief interest centers in those relating to the catalytic production of motor gasoline from gas oil and bottoms, the catalytic treating of raw gasolines, and the production of aviation gasoline by catalytic reforming. Four typical flow sheets, with a summary of physical characteristics of the charges and products, along with yield figures, are given in Figs. 3 to 6 and Tables III to VI. These flow diagrams and data are released by E. B. Badger and Sons Co., the licensing agents, with approval of officials of the Houdry Process Corp. The cases considered are:

1. Production of motor gasoline charging 50% bottoms of Mirando crude. (Fig. 3 and Table III).

2. Heavy aviation gasoline and motor gasoline charging East Texas gas oil 440 deg.—724 deg. F. (Fig. 4 and Table IV).

3. Aviation gasoline 7 lbs. R. V. P. and motor gasoline 10 lbs. R. V. P. by reforming. Initial to 30.9% naphtha cut of heavy Grade B crude (29.7 deg. A. P. I.) (Fig. 5 and Table V).

4. Houdry catalytic treating process results for various catalytic gasolines and blends. Fig. 6 and Table VI).

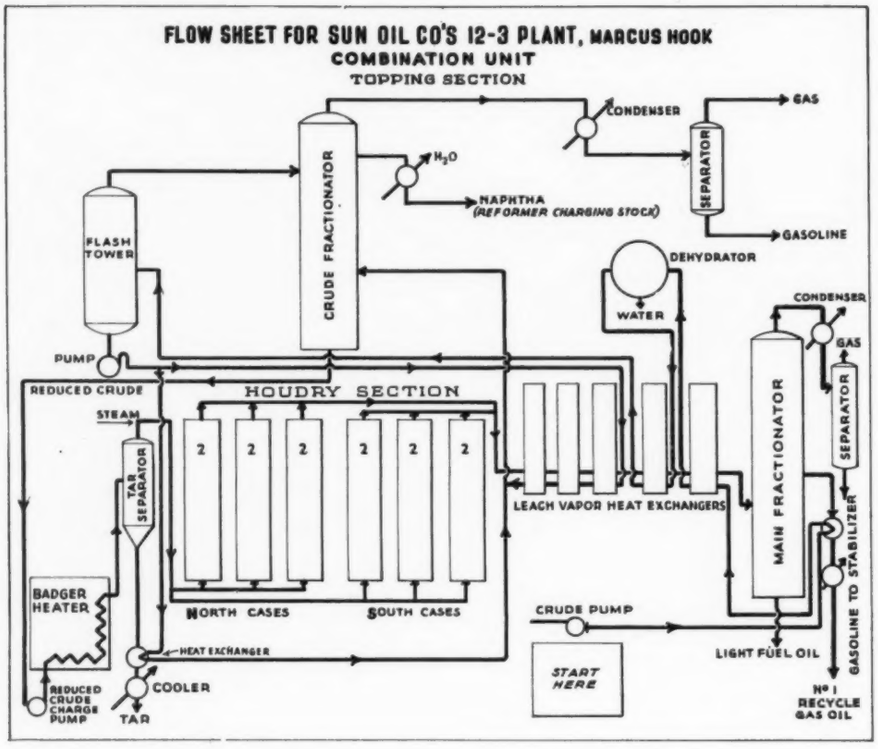


Figure 7

MARCUS HOOK

The new catalytic cracking unit of the Sun Oil Co. at Marcus Hook, Pa., known as the 12-3 plant, is one of the latest installations of the Houdry process. It is a so-called combination unit and has a charging capacity of approximately 28,000 bbl. of crude oil per day. Current operations are on East Texas and Gulf Coastal crudes, the latter being rated as somewhat refractory. Operations at this plant began in July, 1939. The principal operations consist of topping the crude in the conventional manner, charging the bottoms (reduced crude) to the catalyst cases, and catalytically treating the raw gasoline thus produced.

A general idea of the layout may be gathered from the accompanying simplified flow sheet (Fig. 7). It will be understood that the complete equipment includes a maze of pipes and valves, a multitude of pumps, heat exchangers, steam and air supply circuits which if shown on the diagram would bewilder the layman without materially enlightening the expert.

TOPPING

The crude oil is picked up by a pump and sent through a heat exchanging circuit on its way to the topping tower. Heat is first absorbed from No. 1 recycle stock which flows as a side stream from the main Houdry fractionator. The crude oil next passes through the coldest of five vapor heat exchangers through which circulates the cracked vapors coming from the outlet of the catalytic cracking cases.

At this stage the crude has been sufficiently heated to permit the removal of any water it may contain, which is done in a pressure dehydration tank. The settled oil passes from the dehydrator through the fourth coldest of the five Leach heat exchangers and enters a flash tower. The vapors from the latter go to the crude fractionator, where they enter just above the feed plate. The flashed bottoms pass through a crude booster pump, where it separates into two streams. One portion goes through the three remaining Leach vapor heat exchangers, and the other stream passes through the tar heat exchanger; then the two streams join and go to the feed plate of the crude fractionator where the usual topped products—gas, straight run gasoline and naphtha are taken off as overhead, while the bottoms or reduced crude is used as charging stock for the Houdry catalytic section of the unit.

All the preceding constitutes the topping operation as practiced in any refinery, but with this difference: Heat for the topping operation is supplied entirely by heat exchange from oil vapors and products, thereby obviating the necessity of installing a topping heater. This means a substantial reduction of the operating cost of the topped products.

HOUDRY SECTION

The reduced crude from the bottom of the crude fractionating tower is charged through a centrifugal pump to the Houdry section of the unit. In approaching this unit the flow is divided into four parallel streams that pass through a Badger heater designed for gas firing. The fuel gas is admitted from opposite sides with the two fans of flames opposing each other. The flue gases pass toward the center of the heater from the sides, down into two bottom convection sections and back to flues arranged under the firing platforms. This heater is equipped with heat controlling instruments to insure that the heater will vaporize the oil and give the charge enough heat so that the oil and vapor will arrive at the tar separator at the proper temperature, which is about 850 deg. F.

The four heater outlets join into one stream to enter the top of the tar separator, where the hot oil is flashed. The entry of the vapors is made tangentially, so that the tar is separated by a combination of centrifugal force and settling. The tar is withdrawn from the cone-shaped bottom of the separator, at which point it is "quenched" down to 700 deg. F. by circulation of a portion of the cooled tar. The quenched tar leaving the bottom of the separator is pumped through crude-oil heat exchangers built by the Sun Shipbuilding and Dry Dock Company and is then water cooled.

The vapors from the tar separator receive a small percentage of superheated steam to insure that they will be in a completely vaporous state, i.e., above their dew point, before going to the catalyst cracking cases.

The catalytic cracking unit at this plant has twelve cases, arranged with two always in parallel. They are connected in two groups of six cases, each group having its own inlet and outlet manifolds as indicated in the flow sheet.

The present operating scheme for the catalyst unit is for each pair of cases to have an "on stream" period of 10 minutes. The valving system is arranged so that a pair of cases comes on stream every five minutes. This assures that a uniform flow of oil is entering and leaving the cases. The necessary valving is done automatically by motor-operated valves controlled by a single cycle timer, of which more will be said later. The vapors enter the bottom of the cases and leave at the top.

The outlet vapors from the catalyst cases go through the series of five vapor heat exchangers and then to the main fractionating tower of the Houdry unit, along with any condensate that may have been formed. In this fractionator motor gasoline is taken overhead, a No. 1 recycle stock is withdrawn as a side stream, and a very small percentage of heavy gas oil is taken from the bottom. This heavy gas oil is usually blended with the tar product, so that the tar is eventually disposed of as a constituent of Bunker C fuel.

The No. 1 recycle stock is heat-exchanged against crude oil and is then cooled. The overhead from the Houdry fractionating tower goes to a condenser and a gas separator. Just

as in ordinary refinery practice, the wet gas and the raw gasoline must be further processed in the conventional manner in the gas plant and stabilizer.

CATALYST AND CASES

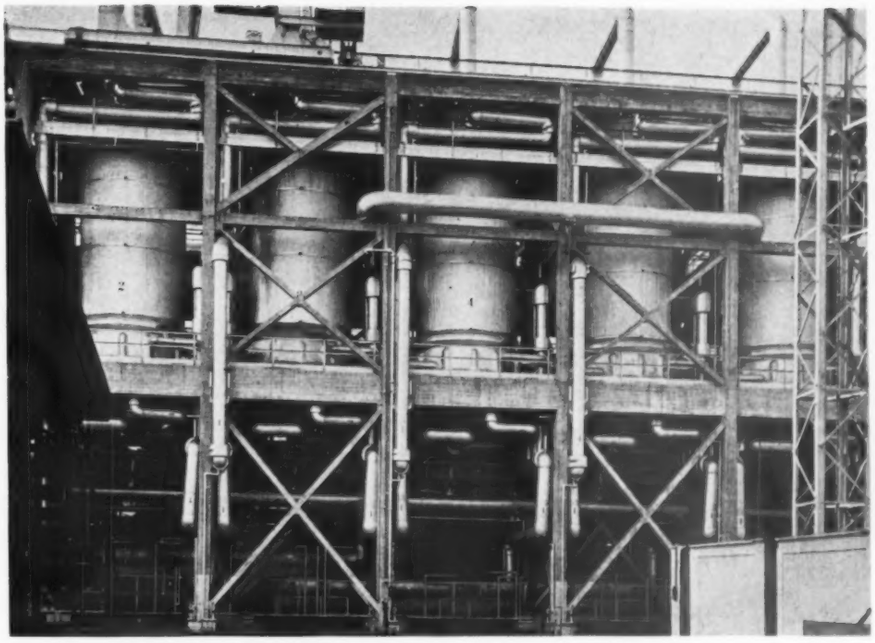
The salient features of the Houdry process are the catalyst (better said catalysts, as there may be a different catalyst for different operations), the catalyst containers or cases, and the method of operating. These features distinguish the Houdry process from the thermal cracking process.

The catalyst is a solid molded product, which as just stated may have different compositions depending on the kind of service expected of them. A typical catalyst is described in United States patent No. 2,078,945, issued to Eugene J. Houdry on May 4, 1937 (date of application: March 23, 1932). The basis of the catalyst mass is a hydrated silicate of alumina, obtained in the form of a natural or acid-treated clay. The preferred composition is given as follows:

Composition of Catalyst Basis

	Percent
SiO_2	76.0
Al_2O_3	16.8
Fe_2O_3	1.6
CaO	2.4
MgO	1.3

Silica and alumina together make up about 93 percent of the total, with about seven percent of inert impurities. For certain operations this material is modified by inclusion of not more than 10 percent of metallic oxides such as nickel, cobalt and others that have been recognized as having catalytic influence. As filled into the cases the mass is molded in the form of small, hard, microscopically porous pellets. From statements by those in a position to know, the preparation of these catalysts is an exacting process, requiring the observance of conditions that will confer on the material the right degree of activity (overactivity is especially to be avoided); crushing strength is an important quality. Impurities that easily flux under the influence of the regenerating temperature are carefully excluded. All Houdry catalysts are manufactured and tested in the factory of the Catalytic Development Company at Marcus Hook. Experience so far has indicated that the useful life of a properly managed cracking catalyst may be indefinitely long, though probably not forever.

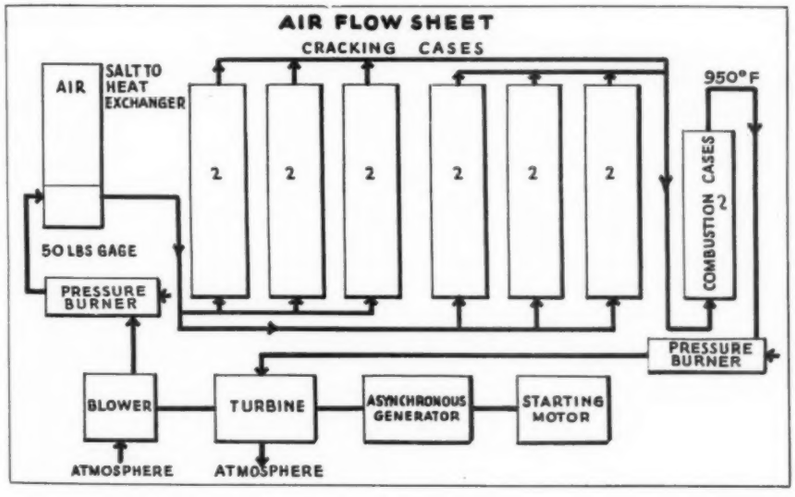


A battery of Leach heat exchangers used in connection with a Houdry unit.

The catalyst cases are cylindrical towers 38 ft. high and 10.5 ft. in diameter constructed by the Sun Shipbuilding and Dry Dock Corporation at Chester, Pa. They contain numerous concentric tubes for circulating the reacting materials. One series of these tubes is for the alternate passage of oil vapors and the air used for burning off the carbon deposited on the catalyst. A second series of tubes conducts the catalyzed oil vapors and the regeneration gases to their respective outlets. A third series of tubes is arranged for circulating a cooling liquid, as a means of keeping the reaction temperatures within limits. The cooling medium in this case is a mixture of fusible salts so chosen that their eutectic point is about 300 deg. F., but which are not decomposed at 1050 deg. F. or somewhat above. The function of this salt mixture is two-fold. In the first place it keeps the catalyst relatively cool during the process of burning off the carbon deposit. This is important, because if the temperature is allowed to go much above 1050 deg. F. the activity of the catalyst is subject to deterioration. To avoid this danger the salt circulating system maintains the regenerating temperature at around 950 deg. F.

On the other hand, the same molten salt mixture serves to keep the temperature at about 850 deg. F. during the period when oil vapors are being circulated through the catalyst mass. The catalytic reaction is endothermic, or heat absorbing, while the regenerating reaction is exothermic, or gives off heat, so a part of the surplus heat given off in one phase of the operation is used to make up a deficiency of heat in the other phase. At that, there remains an excess of heat in the salt which is utilized in the manner indicated further on.

Figure 8



OPERATING CYCLE

At this Houdry plant the cycle of operation for each catalyst case occupies 30 minutes, divided as follows:

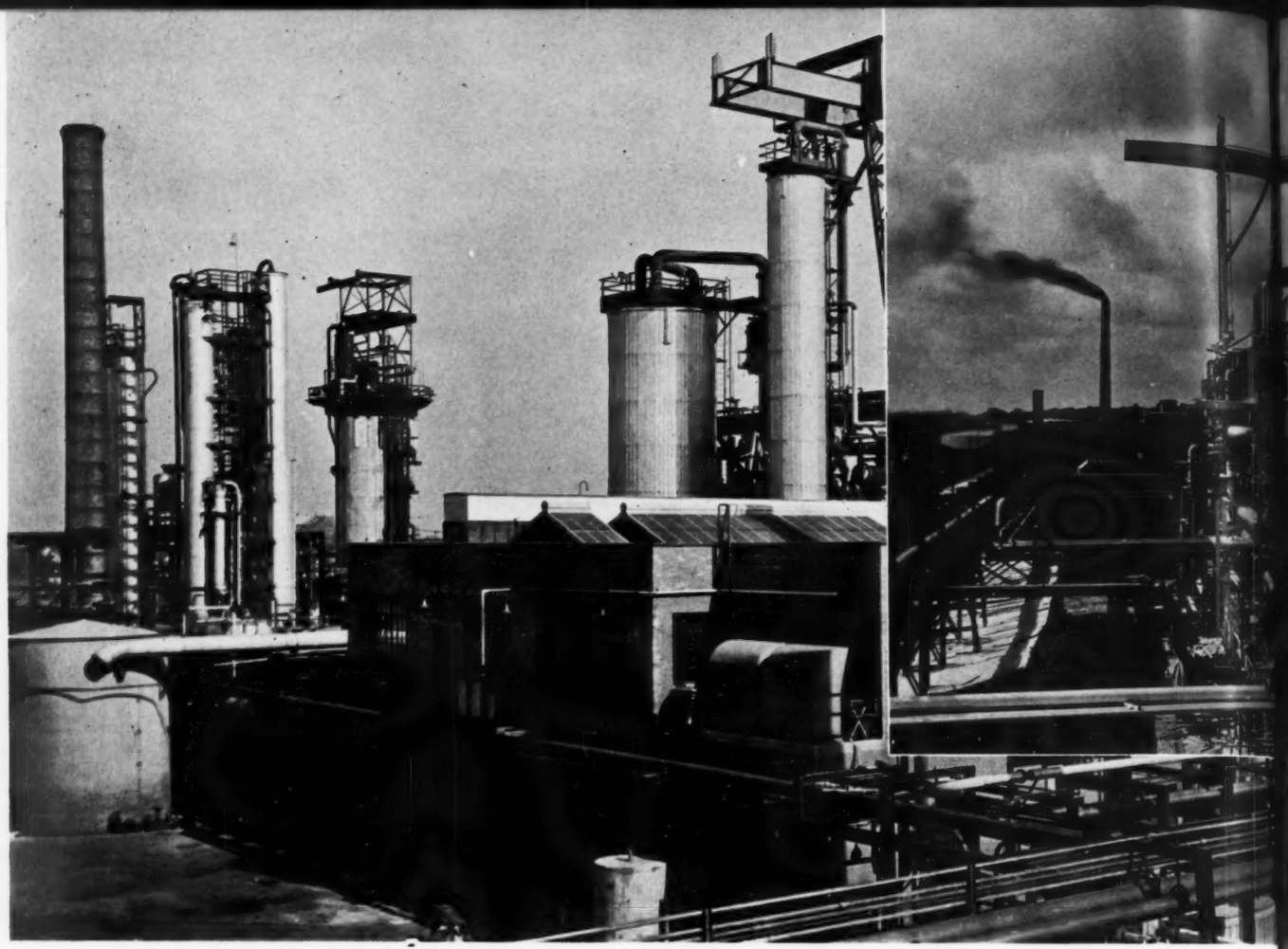
10 minutes on stream while the oil vapors are being catalyzed;

5 minutes for purging the case of oil vapors in preparation for regenerating;

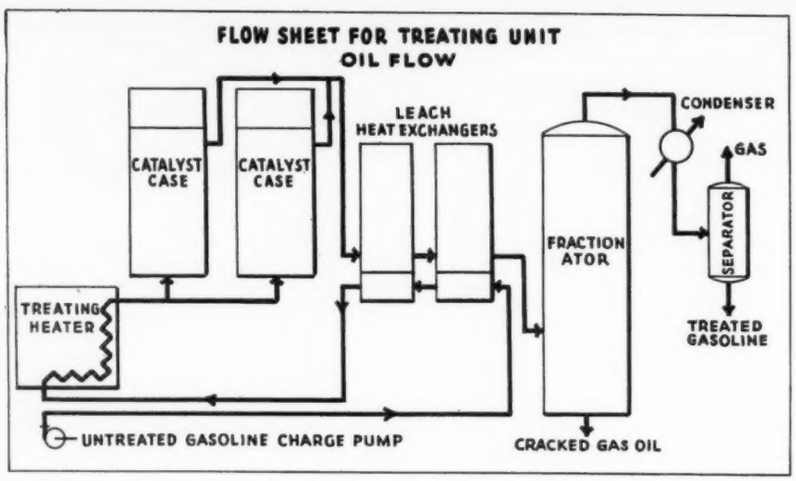
10 minutes for the regenerating operation;

5 minutes for purging the case of air and combustion products in preparation for resumption of catalysis.

The necessity for removing hot oil vapors before admitting air at a burning heat, and



Left, New of 1 unit

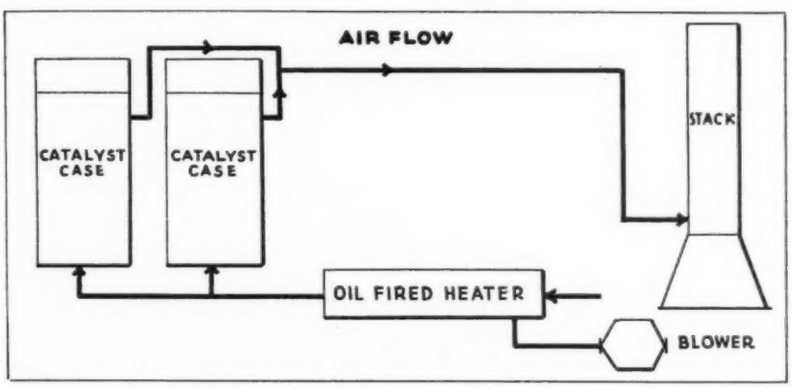


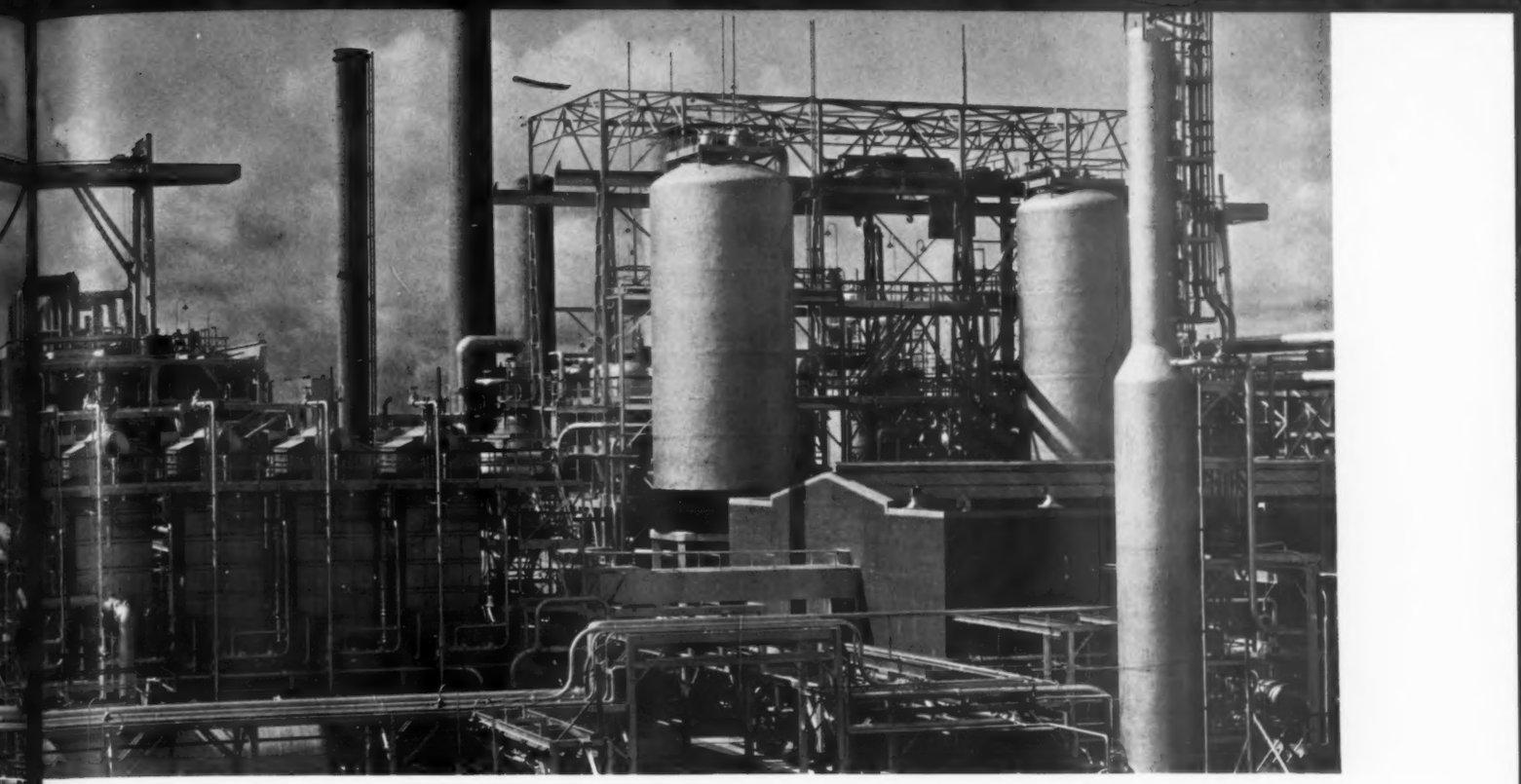
bustion gases pass through a pair of combustion chambers to complete the oxidation of any unburned hydrocarbon vapors and the carbon monoxide produced in regeneration of the catalyst cases. The combustion chambers are filled with a special catalyst the function of which is to reduce the temperature for oxidation of CO to CO_2 and to provide means for recovery of the heat so produced. The regenerating period being a species of dead time, it is important to keep it as short as is

Figure 9, left, Houdry process diagram for treating raw gasoline; Figure 10, below, air flow for treating unit, and Figure 11, right, salt flow for treating unit.

again for removing air before readmitting oil vapors, is obvious: to avoid any chance of back firing. The purging in each instance is done by means of a barometric vacuum system.

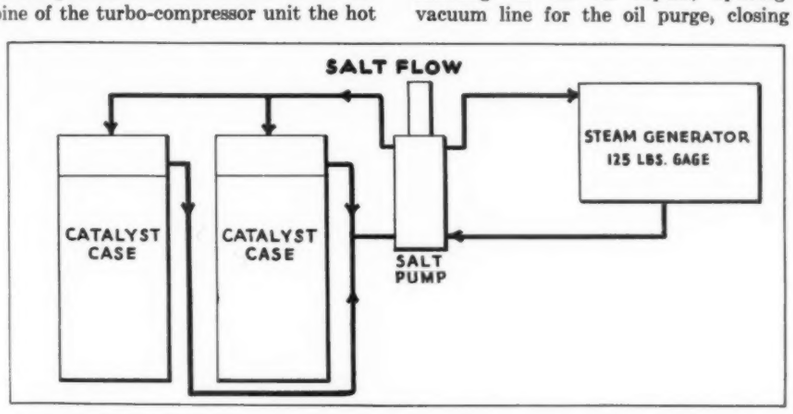
The regeneration with air is one of the most interesting features of the Houdry system. The layout will be understood from the Air Flow Sheet, in Fig. 8. Air is forced by a blower through a heat exchanger where it picks up heat from molten salt circulating from the catalyst cases. It then enters the bottom of the cases at a temperature hot enough to oxidize rapidly the carbon on the catalyst. On issuing from the cases the com-





Left, One of Socony-Vacuum's Houdry units in New York State with a catalytic charging capacity of 10,000 bbl. per day: Above, Magnolia's Houdry unit in Texas; the crane in the left background is used to handle the heavy equipment.

practicable. After passing through the combustion cases the hot gases pass through a turbo compressor unit. On arrival at the air turbine of the turbo-compressor unit the hot



gases, at about 45 lbs. gauge, are expanded to atmospheric pressure and in so doing generate enough power to operate the blower and also a synchronous generator, which converts the excess energy of the hot gases into electric power, which is fed into the refinery electric mains. The starting motor indicated at the right of the synchronous generator is for setting the blower in motion at the beginning of operations. Meanwhile, the molten salts, which have absorbed much heat during the regeneration is circulating through heat exchangers for heating the regeneration air. Besides serving these purposes the salt contains extra heat that is utilized to produce steam at 450 lb. gauge pressure in a special unit constructed by Babcock and Wilcox Company.

CYCLE TIMER

The Houdry catalyst cracking cases run on a rigid time table, making round trips, as it were, every thirty minutes. In each cycle there are a number of valve changes, as follows: opening for the on stream period, shutting off the oil vapors, opening the vacuum line for the oil purge, closing the vacuum line, opening for the regenerating air, closing off the air, opening the vacuum line for the air purge, closing the vacuum line, to begin again by admitting the oil vapors. As these valve changes succeed each other at intervals of ten or five minutes, and since there are 12 cases, manual operation of the valves would require a large crew.

Instead, the valving operations have been mechanized and put under control of a Central Cycle Timer especially built for the Houdry process by the Automatic Temperature Control Co. of Philadelphia. The large room in which this timer is installed is lined with recording indicators that reveal everything of interest that is going on in and around the catalyst cases. The timer is run by a synchronous motor which has contacts for 900 impulses in one complete revolution, which corresponds to one complete case cycle. The impulses transmitted by the timer activate electric motors which open and close the valves at the proper intervals. These openings and closings are reported back to the control room by red and green lights which indicate to the operators whether the plant is functioning normally. If a valve fails to open at the desired time a warning bell is sounded and the tardy valve can be operated by pushing a button which sets in motion a secondary system of control. If any valve still fails to function, or if any other trouble develops, the catalyst case affected may be by-passed without shutting down the whole plant.

GASOLINE TREATING

Associated with the combination plant No. 12-3 at the Sun Oil Company's Marcus Hook refinery is a catalytic gasoline treating plant having a charging capacity in excess of 18,000 bbl. a day.

The operation in outline is indicated in the accompanying flow sheet for the Treating Unit (Fig. 9). As shown in the oil-flow section of the diagram, the untreated gasoline is taken from storage tanks, and after passing through two heat exchangers and a vaproizing heater enters the lower part of one of two catalyst cases. From the top of the case the catalyzed vapors pass through the vapor spaces of the two heat exchangers to help warm up the incoming raw gasoline. They then enter a fractionator tower from which the overhead goes through a condenser into a separator for removal of gas; the bottoms are polymers in the gas oil boiling range. After the on stream period is over the case is purged of vapors and the regenerating cycle begins. Air is preheated by an oil-fired heater and passed into the

bottom of the case and out at the top. (Fig. 10). The heat of the oxidation reaction, caused by burning the catalyst deposit, is absorbed by a salt circulating system (Fig. 11) the tubes of which are concentrated mostly in the top of the case. The combustion gas is discharged into the stack without passing through a turbo-compressor unit as in the cracking section of the plant. The salt system of the treating unit is independent of the one in the cracking plant. The excess heat absorbed by the salt is used to produce steam at 125 lbs. gauge in a special unit.

The accompanying tabulation gives a summary of operations on September 6, 1939, which is regarded as typical of this plant.

The operating regime of this treating plant is relatively simple. The vaporized gasoline enters the cases under moderate pressure at a lower temperature than in the catalytic cracking process. The on stream period may last for several hours. These conditions may be subject to variation according to the character of the charging stock and the results desired. The treating results on various catalytic gasolines and blends from five typical crudes may be seen in the table.

Operating Results, Houdry Catalytic Treating Plant of Sun Oil Company, Marcus Hook, Pa.

Charging stock/24 hours.	11,273 bbl. Catalytic Gasoline 6,861 bbl. Thermally Cracked Gasoline	
Total	18,134 obl.	100 percent
Treated Gasoline Product	17,541 bbl.	96.8 "
Gas Oil	526 bbl.	2.9 "
Gas and Loss	67 bbl.	0.3 "
Total	18,134 bbl.	100.0 "

Tests on Charging Stock and Treated Gasoline

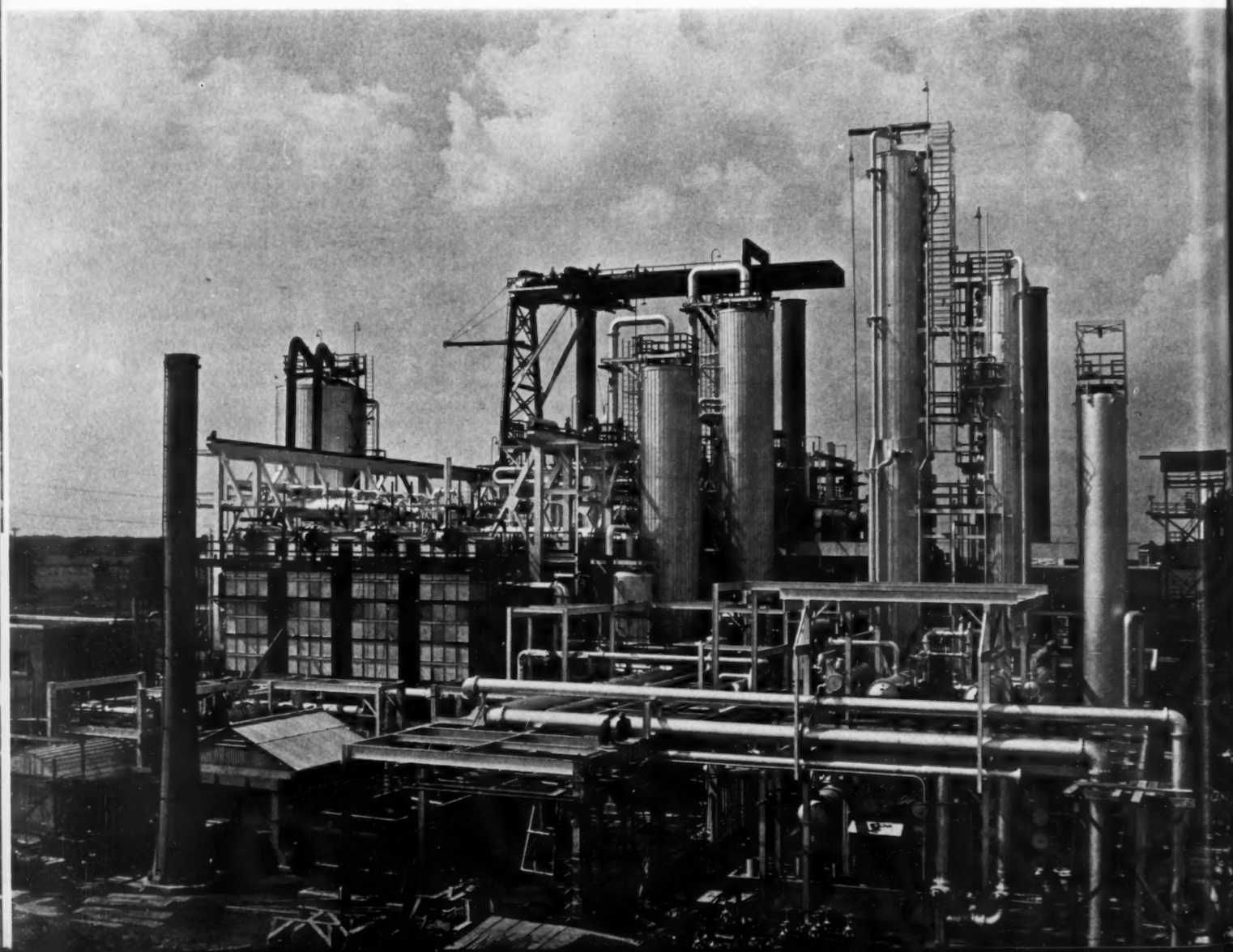
	Gasoline to Treating Cases	Gasoline Overhead from Tower
A. P. I. Gr./60 deg. F		
Initial	53.3 deg. F.	54.3 deg. F.
5%	80	89
10	120	117
20	142	142
30	182	183
40	223	223
50	257	255
60	286	286
70	314	313
80	347	335
90	374	361
95	406	388
End Point	435	411
Color	0	28
Doctor Test	Sour	Sweet
Gum A. S. T. M.	1	1
Gum Cu. Dish	38	8
Oct. No. C. F. R. MM	76.5	77.4
Sulphur	0.03	0.02
Vap. Press. 100 deg.	10.2	10.2

SULFUR REMOVAL

Raw gas from the two Houdry Units at the Sun Oil Company's Marcus Hook plants are treated for removal of hydrogen sulfide by the Girbotol process installed by the Fluor Corporation. The raw gas from both units is mixed, compressed, cooled and delivered to the Girbotol absorber at 60 lbs. gage pressure and at a temperature of 120 deg. F.

A continuous stream of a solution of diethanolamine is pumped into the absorber and flows downwardly counter-current to the ascending gas. The solution, now rich in sulfur enters the reactivator tower at a temperature of 200 deg. F., where it is stripped of hydrogen sulfide by steam at 250 deg. F., which is produced by a reboiler at the base of the tower. The diethanolamine solution, thus regenerated, issues from the base of the reactivator to a pump that elevates it through a heat exchanger and a cooler to the top of the absorber to begin a new cycle.

The hydrogen sulfide and steam issuing from the top of the reactivator flow to a cooler which condenses the steam and cools the hydrogen sulfide. The condensate returns to the reactivator and the hydrogen sulfide is available for a sulfuric acid plant. This operation makes it unnecessary to treat the recovered gasoline for sulfur removal. A further consideration is that the desulfurized dry gas can be used for gas engine fuel or other purposes without the disadvantage of a high corrosion rate.



Combination Houdry unit belonging to Socony-Vacuum and located in the midwest. This unit has a catalytic charging capacity of 10,500 bbl. per day.

CATALYSIS In Petroleum Refining

Study and Experimentation Have Discovered Various Substances which can Alter the Molecular Form of Crude Oil and its Derivatives to Form More Valuable Products—May Lead to Optimum Utilization of All Material.

THE subject of the catalytic treatment of crude petroleum materials to obtain products not easily accessible by other means is now very much in the forefront of interest.

To many persons in the industry the nature and functions of catalytic processes are more or less mysterious subjects, and the increasing number and complexity of such processes that are being offered to the industry is a source of bewilderment to the layman.

In a certain sense catalysis is in fact a real mystery, in that in some aspects its fundamental nature or mechanism is not understood. But it is possible to offer an understandable if empirical definition of a catalytic process. It amounts to this: When a petroleum product is brought into contact with a solid or liquid catalyst the petroleum product is altered in its nature or composition while the catalyst itself remains unchanged, and may be used again to produce the same alteration in fresh quantities of the same raw petroleum product; and so on for a more or less indefinitely repeated cycle of operations, depending on whether the catalyst is protected from circumstances that would destroy its peculiar characteristics.

Usually a catalyst displays its full catalytic properties only under certain definite conditions, such as temperatures and pressures, the rates at which the oil is passed over or through the catalyst etc. It is also a fact that a given catalyst is more or less selective; that is, it will induce certain changes in certain kinds of hydrocarbons but not in others. Also, different catalytic materials affect the same hydrocarbons in different ways, or change them in different degrees. This means that from the standpoint of a petroleum refiner who wants to turn out particular grades of product, catalysts differ in efficiency, so that it may be economical to use one catalyst but not another of the same general kind.

When, therefore, an inventor announces a new catalytic process for refining petroleum, it is to be understood that he has found a material which when brought into contact with certain kinds of charging stock under certain empirically determined conditions will yield one or more marketable petroleum products having certain qualities. A catalytic process thus connotes three main elements: (1) a material capable of effecting catalytic change in a contact operation; (2) a charging stock capable of being altered in a particular way by that catalyst; and (3) a set of operating conditions under which the desired alteration in the nature of the charging stock will take place.

The catalytic processes that are being offered to the petroleum industry are mainly directed toward the following objectives:

(a) To break up hydrocarbons of high molecular weight into products of lower molecular weight (catalytic cracking).

(b) To change the catalyzed products obtained in (a) into more desirable forms (catalytic reforming).

(c) To bring about the union of certain different hydrocarbon elements that, separately, have low commercial values to form a synthetic product of greater value (catalytic alkylation, polymerization and hydrogenation).

CATALYTIC CRACKING

The wordsmiths of the petroleum industry often display a happy faculty for coining accurately descriptive if somewhat picturesque expressions. One of these is "cracking", and cracking is exactly what it is. The molecules of a crude petroleum residue or a gas oil are composed of large, long, non-volatile, sluggish (viscous) chains of carbon atoms and have none of the highly mobile, volatile and easily inflammable properties desired in a motor gasoline, and which are still more desirable in an aviation gasoline. When the Burton thermal cracking process was invented some thirty years ago the petroleum refiner found that by using heat and pressure he could "crack" the long, heavy molecule of a gas oil or residue into two or more smaller ones, and thus increase the supply of liquid products boiling in the gasoline range.

The Burton thermal cracking process and its numerous later modifications provided the necessary condition for a widespread use of the automobile, which would not have been possible without an abundant supply of cheap motor fuel, and thermal cracking is today by far the main reliance of the gasoline manufacturer. However, in the present state of the thermal cracking art there remain certain imperfections. Ideally, all the long molecules in a petroleum residue should be cracked into smaller pieces of just the right size and form with none of the material flying into fragments that are too small (gas), or agglomerating into forms that are useless as motor fuel, such as tar and coke.

It is these imperfections of thermal cracking processes that inventors of catalytic cracking systems have essayed to improve. To be a real improvement on the prior art, a catalytic cracking process would have to take the same raw material and produce more and better gasoline molecules and less of undesirable by-products without unduly increasing the unit cost of production.

To what extent the inventors of catalytic cracking processes have succeeded in attaining these objects may be left to the judgment of refinery engineers before whom the case of catalytic cracking vs. thermal cracking is brought for decision on their commercial merits. This discussion must be confined to what is known or suspected as to the nature of a catalytic cracking process.

What is known is that when a gas oil or a residuum is vaporized and passed through a container filled with a porous mass of material which has previously been found to have catalytic properties, the heavy molecules of hydrocarbon are cracked at a lower temperature and generally at a much lower pressure than in thermal cracking. It is particularly noted that the cracking seems to occur with much less effort, as it were; that is, more of the heavy oil molecules are cracked into gasoline molecules at one passage of the material through the catalyst mass, whereas to obtain the same amount of gasoline in an average thermal cracking process may require several passes; in these multiple passes relatively more of the recycled stock is broken up into gas, tar and coke. It has also been noted that catalytically cracked gasoline is of a better quality as a motor fuel, as measured by its octane number.

THEORY OF CATALYSIS

How and why a catalyst acts that way is not clearly known, but much has been suspected. It is supposed that in some undisclosed way the catalyst loosens the middle bonds of the long molecular chains so that they come apart of themselves rather than by a violent smash, as in thermal cracking. It has also been supposed that most of the molecules of thermally cracked gasoline still closely resemble the long-chain molecules from which they were produced; that is, they are still made up mostly of chains of CH_2 groups, only the chains are shorter. It is generally considered that the presence of these predominately straight chained fully saturated hydrocarbon molecules in a thermally cracked gasoline is responsible for the tendency of such gasoline to knock in the automobile engine, which is associated with a lower octane rating. On the other hand, it has been supposed that the somewhat better octane rating of a catalytically cracked gasoline is due to the fact that more of the molecular fragments have been rearranged by the catalyst into cyclical or branched forms, or are converted from members of the paraffin series into members of the olefin series, all of which contribute toward higher octane values.

Some oil technologists are inclined to think that thermal and catalytic cracking will eventually complement each other, chiefly for economic reasons. One such reason is that the catalytic processes now mostly in the forefront of interest require large initial capital investments. It has been suggested for instance, that catalytic cracking supplies a gas oil that makes an excellent charging stock for a thermal unit, and that a combination unit for the catalytic treatment of thermally produced gasolines is more economical than a plant exclusively for catalytic operations.

However, the matter at present appears to be in a state of flux, due to the fact that the field of catalysis and the list of possible catalytic cracking agents is more extensive than had been supposed; and this is true also of the forms of the methods of using catalysts. There are two general classes of materials that come into consideration as catalysts: natural or treated clays, and metallic oxides; the former are cheaper, the latter are said to be more efficient if somewhat more difficult to manage. Then there are two types of catalytic processing. One is an intermittent type in which the process requires at least two catalyst cases, one to be in operation while the other is shut down for regeneration; the other type requires only one case in which the oil vapors and the catalyst move countercurrently, the catalyst being regenerated outside the reaction case and returned to the case in a continuous stream.

At the present time, catalytic cracking of a crude oil has become a large scale proposition in various forms of the Houdry process and is being applied to various charging stocks (mostly topped crudes) with various objects in view, such as predominately for the production of light gas oil, or predominately for the production of gasoline. For attaining these objects the composition of the catalyst and the operating conditions may be varied within wide limits. A more detailed outline of the Houdry catalytic cracking process will be found elsewhere in this number of WORLD PETROLEUM.

CATALYTIC REFORMING

The raw gasoline produced in a cracking operation whether catalytic or thermal is seldom a perfect product. As mentioned above, the main function of the cracking operation is to break up the large hydrocarbon molecules into smaller ones. While the fragments produced by catalytic cracking may be more uniform, more rounded or more olefinic than those produced by thermal cracking, they still, in a manner of speaking, have rough edges which it is desirable to smooth down. For this purpose the gasoline is vaporized and again passed through a catalyst mass. Usually the catalyst employed in this reforming operation is of a composition and activity different from that employed in the main cracking operation, and the operating conditions—temperature and pressure—are also different. It may be repeated that these variations in the nature of the catalyst and the conditions of catalysis are not predictable from any general rule, but must be learned as a result of extensive experiment.

However, the reforming process still resembles cracking, only in a milder form. Detachable groups in the oil molecules are loosened and caused to rearrange themselves in forms that have less tendency to knock in the automobile, so that the general effect of reforming is to raise the octane number of the gasoline. Further, the raw cracked gasoline contains some badly shattered unstable substances that would undergo progressive deterioration when the gasoline is stored, forming gum. Under the mild action of reforming catalysis these crippled molecules are either healed by having new components grafted on them or are otherwise reformed so that they can still remain in the range of stable gasoline, or else they are caused to polymerize into heavier products that may be removed when the reformed gasoline is sent through the fractionating tower.

Catalytic reforming is applicable not only to catalytically cracked but also—and even more so—to thermally cracked gasoline. Raw thermally cracked gasoline is distinctly "rawer" than the catalytically cracked product, and hence is susceptible to a wider margin of improvement. A thermally cracked raw gasoline can be and more generally is now reformed by an appropriate thermal treatment, but from published results it appears that catalytic reforming has a distinct advantage in both quantity and quality of the product.

This phase of catalysis in the refining industry has more especially aroused expectations among the medium to small refiners, who have been told that catalytic cracking is more or less out of their reach on account of the comparatively large initial investment required for economical operation. The case is somewhat different with catalytic reforming, where the first cost of a catalytic reforming unit, and especially the larger yield and the relatively huge improvements in the octane rating of thermally cracked gasoline, seem to make thermal cracking and catalytic reforming natural partners in the service of the smaller refineries. Here also the matter is in a state of flux between the merits of different catalytic reforming agents and different methods of operation, so much so that an opinion has been expressed that present ideas about catalysis will probably be outmoded within the next two years, and almost certainly within the next five years.

Catalytic reforming is not a new development in petroleum refining. Attempts to improve the quality of thermally cracked gasoline by passing it over clayey materials under heat and pressure date back twenty-five years or more, with no commercial success. These early failures were largely due to insufficient preliminary research to determine the separate influences of the numerous factors involved, particularly as regards the nature and composition of the catalyst. Up to that time the main reliance of the refiners for correcting the faults of cracked gasoline was (and to a large extent still is) a treatment with sulphuric acid, a process which has well known inconveniences. The main function of an acid treatment is to destroy gum-forming substances, which also involves destruction of other values.

SOME PROCESSES

These inconveniences were avoided to a considerable extent by the Gray clay treating process which was introduced after the great war and was commercially successful. In the Gray process the cracked gasoline in the vapor phase was passed over a catalyst (Fuller's earth) at 375-400 lbs. pressure. The principal talking-point of the Gray process was that it acted selectively on the gum-formers, which are present in the form of unstable, unsaturated hydrocarbons. These substances are caused by the catalyst to polymerize or agglomerate together to form considerably larger hydrocarbon molecules, some of which have boiling points too high for them to remain in the gasoline, and so are removed in the distillation that follows the treatment. Other valuable constituents of the gasoline, which would be destroyed by an acid treatment, are left undisturbed. This idea of catalytic polymerization, which in the Gray process was regarded mainly as a means of getting rid of undesirable unsaturates, has more recently been developed into a valuable system of obtaining new and decidedly important petroleum products.

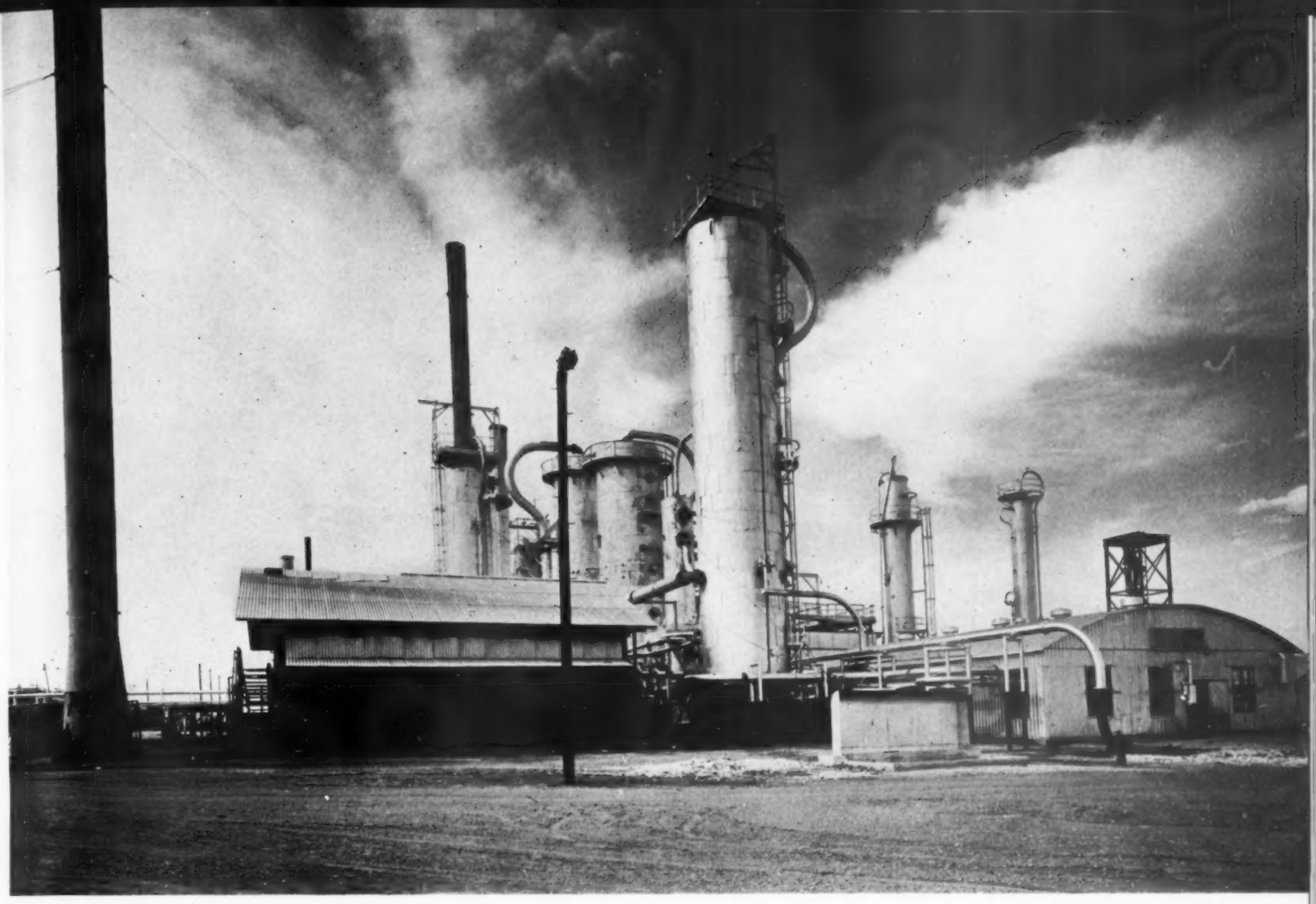
Several variants of the Gray process have appeared. Among them is the Osterstrom process in which the gasoline, instead of being vaporized, is passed over the clay as a liquid under about 1000 lbs. pressure.

Another variant is the Stratford continuous process of clay treatment. In this process the raw gasoline is vaporized and is passed upward counter-currently to a descending slurry of clay suspended in naphtha.

This idea of continuous catalytic treatment of raw gasoline for reforming purposes appears to be attractive from the standpoint of cost of installation, cheapness of catalyst, ease of operation, and quality and yield of finished gasoline. One advantage claimed for it is that the spent catalyst can be regenerated outside the operating cycle, in contrast with the intermittent process where the catalyst case is by-passed for regenerating the catalyst *in situ*.

The process of Houdry catalytic reforming is now well known and if everything that has recently appeared in print can be taken at its face value, other very interesting developments are on the way. The Phillips Petroleum Company has been credited with the development of a long-lived, cheap bauxite catalyst which is so efficient that reforming expense assignable to catalyst cost is well under one cent a barrel. This bauxite reforming catalyst is said to have not only the advantage of low cost, but gives distinctly higher yields of higher octane number gasoline, and removes 75 percent of the sulfur, including 95 percent of the mercaptan sulfur contained in Mexican gasoline, which vastly increases the lead susceptibility of the finished product.

Aside from this new bauxite catalyst, about which few details have been given out, hints have been published concerning a new syn-



Control room, residue gas manifold on right; gasoline receivers in center; and absorption tower on left of the Cosden refinery at Big Springs, Texas.

thetic catalyst (composed of metallic oxides), about which still less information has been furnished. This process is said to be a once through operation which gives high octane number gasoline and can be installed in economical units of 3000 bbl. daily capacity, and may be built as a continuous reforming unit costing 60 percent as much as the intermittent type. An interesting point about the product from this process is the alleged fact that the heavy end of the motor fuel is as high in octane number as the light end. Gasolines with end-points of 437-450 deg. F. are said to be satisfactory, which naturally is of benefit to the overall yield. It is said that in this process the paraffinic constituents are largely converted into aromatics, although little benzene is produced. This conversion of long molecules into round or cyclic molecules, to which the improvement in octane number is largely ascribed, illustrates the function of catalysts in general to produce their reforming effect by rearrangements of molecular structure.

While definite information about this new synthetic reforming catalyst is lacking it has been stated on apparently good authority that several units of this type, totaling more than 40,000 bbl. of daily capacity, are under construction or design, and it is further stated that the process may be available in rather small units. If all that has been published as fact or supposition turns out to be the truth, the small refiner need not remain handicapped by high installation costs in the competitive race to produce motor fuel of higher and higher octane rating.

CATALYTIC POLYMERIZATION

When a crude petroleum residue or gas oil is cracked, whether thermally or catalytically, the hydrocarbon molecules undergo a general breaking up and the resulting fragments are more or less extensively recombined and reshuffled to produce a mixture of low-boiling hydrocarbons that forms the basis of a commercial motor fuel. In the hurly-burly that goes on in the hot cracking zone some of the molecules lose part of their hydrogen; this is dehydrogenation. The hydrogen that has been knocked out of these molecules is absorbed by other molecular groups—hydrogenation. Molecules of the same kind may be forced to double or triple up to form larger molecules—polymerization. Molecules of different kinds may also be forced to unite in new and larger complexes—alkylation.

When this mixture of dehydrogenated, hydrogenated, polymerized and alkylated products, together with miscellaneous fragments of the large molecules of the original crude issues from the cracking chamber, it is separated into a condensed liquid portion, which constitutes the raw cracked gasoline and an uncondensed portion which constitutes the refinery cracked gas. As was remarked above, the raw cracked gasoline is still not a finished product, in the sense that it is subject to improvement by a further process of dehydrogenation, hydrogenation, polymerization and alkylation. This is accomplished by a reforming operation, which in reality is merely a re-cracking under milder condition. The re-cracking or reforming may be done either thermally or catalytically; as stated previously, catalytic reforming appears to have advantages that have aroused lively expectations. The products of reforming are finished gasoline and some more refinery gas.

Even a reformed gasoline might be somewhat improved in quality by further reforming, but having obtained a good yield of marketable gasoline the refiner's object is mainly accomplished as far as his chief liquid product is concerned. There still remain the liquefiable light products and the more or less permanent gases that cannot be incorporated in commercial gasoline. But the fact is that these light products contain substances that have large potential value that may be developed if they are severally or collectively subjected to alkylation, polymerization and/or hydrogenation, thus completing a job that was left not wholly finished in the cracking and reforming stages.

The substances that now come first into consideration are the light olefins of the C_3 and C_4 carbon groups; the C_3 constituent is propene, ($C_2CH{:}CH_2$) which is propane ($CH_3CH_2{-}CH_3$) minus two hydrogen atoms, which were

lost somewhere in the cracking process. The C_4 group consists of several butylenes one of which is $C_2CH_3CH{:}CH_2$, which is a butane that has lost hydrogen. The point of importance here is that the places where the hydrogen was knocked out of the molecules are reactive, ready to join up with any suitable substance that presents itself under favorable conditions of temperature and pressure, or in the presence of a proper catalyst. For instance if nothing else presents itself, two molecules of iso-butylene will join up (polymerize) to form a C_8 group, namely iso-octene, which, when hydrogen is subsequently added (hydrogenation), becomes iso-octane, which though not a gasoline in itself is highly prized for its ability to boost the octane number of ordinary gasoline, and as a constituent of high grade aviation fuel.

The object of the refiner is now to bring about this polymerization, that was not completed in the cracking and reforming stages, by treating the light ends in a separate operation. To a certain extent the polymerization may be effected by heat and pressure, but more surely and completely by catalysis.

Various substances have been used as polymerizing catalysts. In the Lachman process the catalyst is zinc chloride. In the Universal Oil Products Company process it is solid phosphoric acid. The latter process, of which there are now numerous installations, is directed mainly to the cracked refinery gases, particularly stabilizer gas, though both kinds of gas may be combined for treatment. These gases are compressed and heated to 350-400 deg. F. and sent through long narrow towers filled with a solid phosphoric acid catalyst. The gases contain from about 20 to about 40 percent of propene and butenes, the rest being inert materials in this reaction. Under the catalytic influence of the phosphoric acid the vacant bonds of the propene-butenes mutually seize each other and thus unite to form larger molecules that come within the gasoline boiling range, and bring with them valuable anti-knock qualities. By thus catalytically treating gases that would otherwise be wasted or sold at low prices, the refiner may increase, his overall yield of gasoline by 8 or 10 percent, and at the same time gain one or two octane numbers for his entire output.

Universal Oil Products Company has also developed this catalytic process to a point where iso-octane can be prepared as a separate operation.

Houdry Process Corporation has a catalytic polymerization process directed more especially to the butylene constituents of stabilizer gases, whereby these C_4 constituents are polymerized in the liquid phase into a product consisting of C_8 and C_{12} groups, and gas oil. The resulting gasoline is said to have a gravity of 57 deg. A. P. I., an octane rating of 84 to 86 and a blending value as high as 136. This latter fact indicates that the quality of a catalytically polymerized hydrocarbon may be of much greater interest than its quantity. The polymer obtained in this process which is still an olefin is said to be an excellent base stock for preparing iso-octane by a process of catalytic hydrogenation.

ACTIVATING BUTANE

In this Houdry catalytic polymerization process the charging stock is (as was said) a stabilizer gas containing around 28 percent of butylenes, the rest consisting of butanes. The point to remember here is that a butylene is a butane that has lost some of its hydrogen in the cracking process; in a manner of speaking the butylene molecule has a wounded surface on which something may be grafted, and so it is susceptible to polymerization. The uninjured butane molecules, which have retained all their hydrogen, come through the catalyst case without change. From the standpoint of a more remunerative utilization of all petroleum products this aloofness of the butane molecule is regrettable. It is true that butane has a certain commercial value; it confers volatility on heavy gasolines and can be compressed and sold as liquid gas, but these outlets can hardly manage the large amounts of butane that are found in natural gas and in cracked refinery gases.

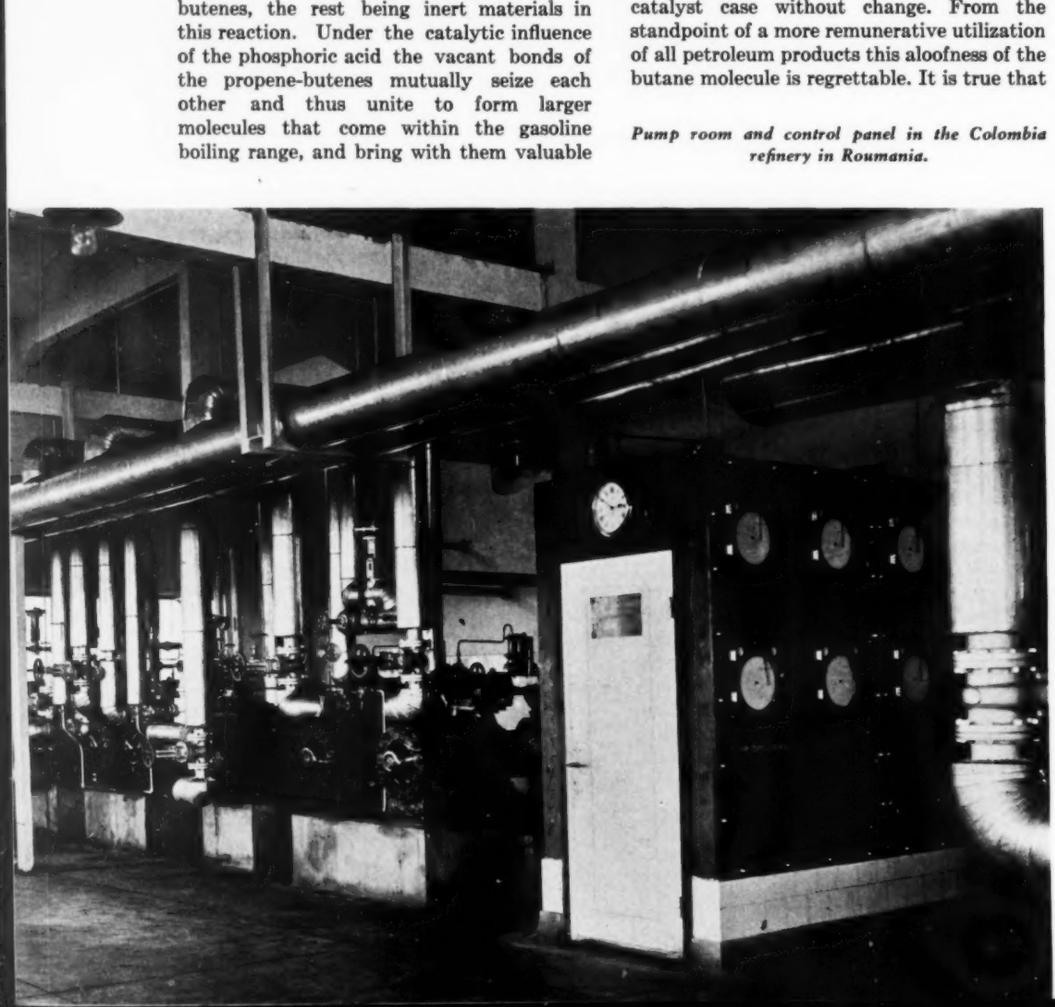
It now appears that catalytic processes have been devised by which butane may be induced to become reactive. The Shell and Texas companies are said to have made considerable progress in this direction. The catalyst is sulfuric acid and the charging stock is a mixture of isobutane and normal butane with isobutylene and normal butylene. It will be noted that this mixture consists of injured (dehydrogenated) and uninjured butane molecules. Under the influence of the catalyst the structure of the uninjured butane is loosened so that it can join up with the dehydrogenated butane (butylene) and the result is iso-octene *et al*, which in a separate catalytic hydrogenation process is converted into iso-octane, the high blending value of which is well known.

The statement that the product of this catalytic reaction is iso-octene *et al* calls for a brief explanation of nomenclature. When two or more molecules of iso-butylene join up the act is polymerization, and the product is a polymer. When two unlike molecules such as butane and a butylene combine the act is a condensation or alkylation, which is sometimes referred to as being distinct from polymerization. It will be understood that in a catalyzed mixture of butanes and butenes there will be indiscriminate union between like and unlike elements, and the final product is a mixture of what are called copolymers.

There are two variants of the sulfuric acid process of catalyzing a mixture of butanes and butylenes to produce iso-octane and its congeners as the final product. One is a cold process, using 98 percent sulphuric acid at a temperature of about 45-60 deg. F.; this process produces iso-octane directly. The other variant is the hot process, using 67 percent sulphuric acid at about 175 deg. F. The product is iso-octene and polymers, which is cleansed of sulphur, mixed with hydrogen and catalyzed to iso-octane by a nickel catalyst (supported on porcelain) at a temperature close to 400 deg. F.

However, the charging stock for all the catalytic polymerization and alkylation processes above mentioned are limited to the quantity of butylenes available in refinery cracked gases and there still remains a surplus of butanes. A natural thought would be to knock out some of the hydrogen of these butanes and thus enlarge the supply of butylenes to be combined with the rest of the butane in the production of iso-octane and other constituents of the much desired superfuels for automobile and aviation engines.

It has recently been stated that this idea has been put on a commercial basis by the Phillips Petroleum Co. Complete details have not been given out, but it appears that the process involves several catalytic steps. First the saturated hydrocarbon is separated as a fraction of natural or light refinery gasoline and divided into two parts, and no preliminary treatment is given the one part consist-



Pump room and control panel in the Colombia refinery in Roumania.

Looking northwest at the Watson, California refinery of Richfield Oil Company.

ing essentially of pure iso-butene. The other part, which may consist of butane or other hydrocarbons, is catalytically cracked to produce a desired quantity of olefins; these latter are then catalytically reacted with the uncracked iso-butane to effect polymerization and/or alkylation of the various elements. The olefin polymers are catalytically hydrogenated to produce iso-paraffins of 95-100 octane number. Any overpolymerized heavy products are catalytically recracked to reduce them again to the desired boiling range. It is said that these results may also be obtained by appropriate thermal methods, which apparently means that a decision has yet to be made as to which method is the more desirable.

A further natural thought is to extend this purposed production of butylenes from butene downwardly on the hydrocarbon scale to include the more refractory gases propane and ethane, which also largely compose natural and refinery gases. It is claimed on behalf of the Phillips Process that this idea has been realized. A light fraction, consisting essentially of ethane, is cracked to produce mainly ethylene, which is reacted with iso-butane to produce neo-hexane (2-2- dimethyl butane) which is said to have extraordinary properties as a motor fuel and to be an immediate source of the 115-octane number gasoline for which the automotive technologists are waiting. However, it appears that neo-hexane is being produced by thermal methods, which removes it from the present discussion.

Of late considerable attention has been given to catalytic desulfurizing processes. Houdry Process Corporation has developed such a process which has not been publicly described. In one of his patents Houdry uses a nickel compound for absorbing sulfur, which is subsequently burned off under conditions that will not result in formation of nickel sulphate. A process of that kind comes under the head of chemical action rather than under catalysis. However, announcement has recently been made of a real catalytic desulfurizing process in which the catalyst is bauxite. The catalyst is said to eliminate the major proportion of the sulfur, thereby appreciably raising the octane number and the lead susceptibility of the gasoline.

The introduction of catalytic hydrogenation into the petroleum refining industry is due not so much to the discovery of hydrogenating catalysts, as to the discovery that certain petroleum products can be hydrogenated with advantage, using a nickel catalyst. The conversion of unsaturated oils into saturated products is an old story in chemical industry, for example the hardening of cottonseed oil. If a hydrocarbon product will take up hydrogen at all, there will usually be no trouble in devising a hydrogenizing process for it. So far, the chief use of hydrogenation in petroleum refining has been the conversion of unsaturated olefins into more desirable products, as for example the transformation of octenes into octanes.

No special reference is here made to the great part played by catalysts in the production of synthetic petroleum by hydrogenating coal. This division of petroleum technology has reached a great development in European countries where petroleum resources are scanty. Coal is catalytically transformed into hydrocarbon either directly, or after conversion into water gas. Tars and asphalts may also be converted into gasoline and lubricating oils by means of catalysts.

If the American refining industry ever finds it of commercial interest to do so, it could catalytically transform even its tar and its coke into its regular products. By catalytic processes it has begun to appropriate more of the values contained in the propane and ethane that heretofore have not found desirable outlets. No easy method of utilizing the excess of methane has appeared, but eventually this may also succumb to catalysis.

Demand for Aviation Fuel Coincides with ERA OF CATALYTIC CRACKING

By Dr. M. B. Cooke

THE outbreak of the second world war on September 1, 1939 brought with it a quickening of interest in fuels for aeroplane motors. This new and virile war machine demands the best fuel and in large quantities. Where is this tremendous quantity of fuel coming from? In the United States it is not so much a cause for worry as in Europe and Asia. With large refineries and great numbers of automobiles, plants have been planned and built on the same grand scale. It is now likely that part of Europe at least, will call upon the United States for considerable quantities of high octane aviation fuel. Expansion in defense in the United States also calls for more planes and the fuel to feed them.

The problem of more power output per pound weight of aviation engines has definitely been along the line of higher octane fuel. It may be of interest to mention some of the modern developments in the production of motor gasoline of higher octane, for such work has paved the way in a lot of cases for the manufacture of aviation gasoline. The older major operations in a refinery have become the accessories in a modern plant. It is now customary to build a cracking plant of some sort as the major attraction and pile on a few distillation columns and viscosity breakers as accessories.

During the past few years the refiner has been kept busy trying first of all to see how he could make gasoline better in quality to suit the requirements of modern engine design; and to accomplish this for less money.

The Bari plant in Italy, one of the sources of fuel for Italian planes.

The major cycles which have occupied the stage during the past fifteen years are, as follows:

To 1925—Distillation of crude oil followed by cracking of the gas oil cut for additional gasoline production.
1925–1930—Development of the modern combination crude oil cracking units.
1930–1935—Introduction of viscosity breakers, reforming units and polymerization plants.
1935–1940—Research and development leading to the modern high octane gasoline producing plants such as:
(1) Reforming of naphtha,
(2) Polymerization of unsaturated gases followed in some cases by pyrolysis of saturated gases to unsaturates,
(3) Production of iso-octane,
(4) Production of aromatics from petroleum gases by pyrolysis,
(5) Catalytic reforming and catalytic cracking.

The combination operation wherein reforming of straight run naphtha is combined with a thermal polymerization plant is an example of cooperation. The result is of interest to most refiners of mixed base or paraffinic crude oils. In order to get a better perspective of just how good this combination is, it is opportune to go back a little and see what reforming was and is doing for the refiner and for the consuming public.

REFORMING VIRGIN NAPHTHA

A considerable amount of work has been carried on with the view of obtaining a more volatile, higher octane product from naturally occurring naphthas since they are in between gasoline and kerosene. With the exception of a relatively small market for solvents and diluents, naphtha has been the unwelcome cousin in the lighter end of most crude oils. It is no good for motors and is too volatile for kerosene lamps, etc. A great quantity of this paraffinic, poor octane naphtha has become available with the flush production of East Texas, Iran and similar crude oils. The first process to suggest itself was reforming since it is a relatively simple thermal treatment operation and produces an increase in octane number of 20-40 points with a tolerable loss in volume, the latter being in the form of either unsaturated and saturated gaseous hydrocarbons and fuel oil or tar. During the past few years we have heard of reforming's half sister, naphtha reversion, reversion being used apparently in a new and improved form. With so many new titles to pick from, the refiner has been busy cross-examining the process equipment men to find out if he was buying an oil plant or a soap factory. It appears that naphtha reversion really is a reforming operation actually performing a thermal poly operation of the unsaturated normally gaseous hydrocarbons at the same time. Since the second operation is exothermic and reforming is endothermic, it is theoretically on the right hand side of the ledger of economics. The practical aspects are not all clear as yet.

When presented with this imposing list of new processes to be set up in the refiner's yard, the refiner naturally bases his choice largely on economic criteria.

First of all, reforming of naphtha is a pyrolytic reaction transforming paraffinic hydrocarbons into other families such as olefins, naphthenes and aromatics. The latter are higher in octane value than the old Pennsylvania aristocracy paraffins. The aim then in reforming is to see how many paraffins can be converted into the more desirable ring families and still not set up a gas production plant. The reactions which occur in naphtha reversion are of the same type as are found in simple reforming but the polymerization factor becomes more influential. The time-temperature relationships in the furnace coils are about the same as would be used in a combination of reforming and thermal polymerization. Naphtha reversion appears to hold more promise of higher ultimate octane values for the product than does the combination just referred to, i.e., reforming and thermal polymerization. The disadvantages of naphtha reversion appear to be the recovery of the recycle gases which runs up the plant installation and operating costs. By a combination of reforming and thermal polymerization, on a typical Mid-continent naphtha, a 70-75 octane product may be obtained

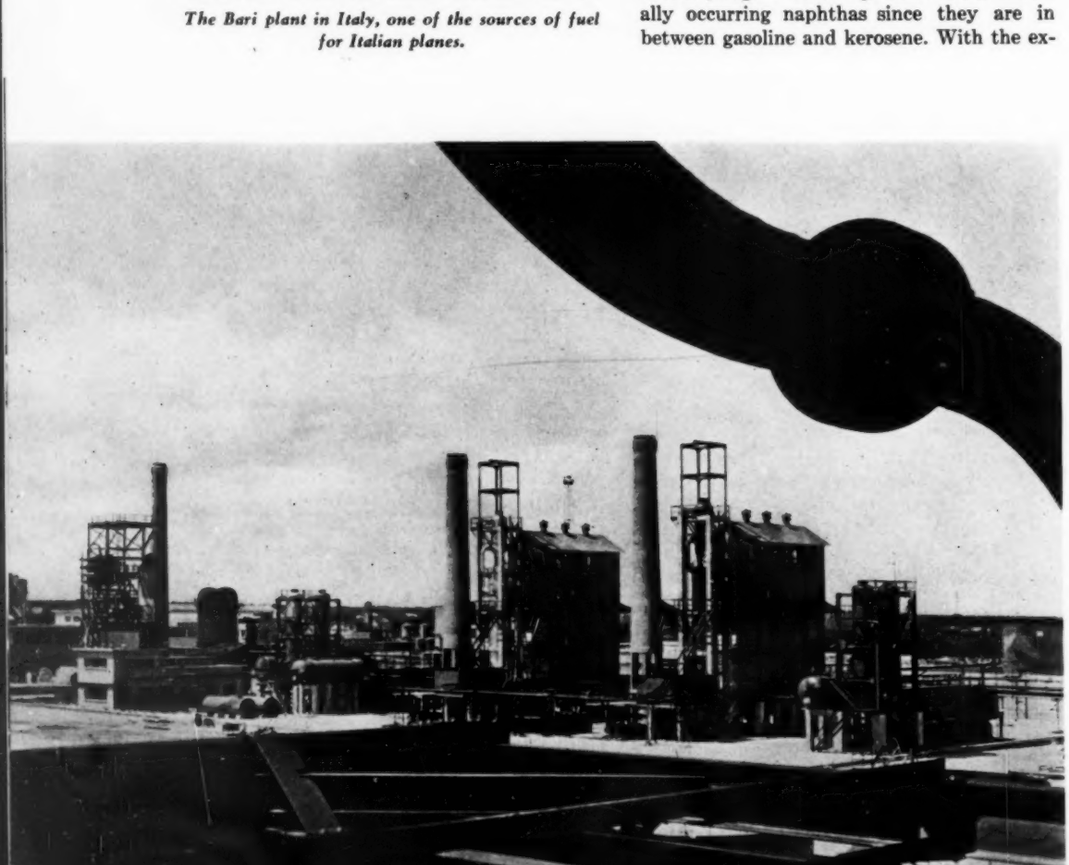


Photo by U. S. Army Signal

Above, huge fleets of army and navy planes have made necessary new processes to supply maximum quantities of high octane fuel, and right, pipes to underground storage at Bari, Italy.

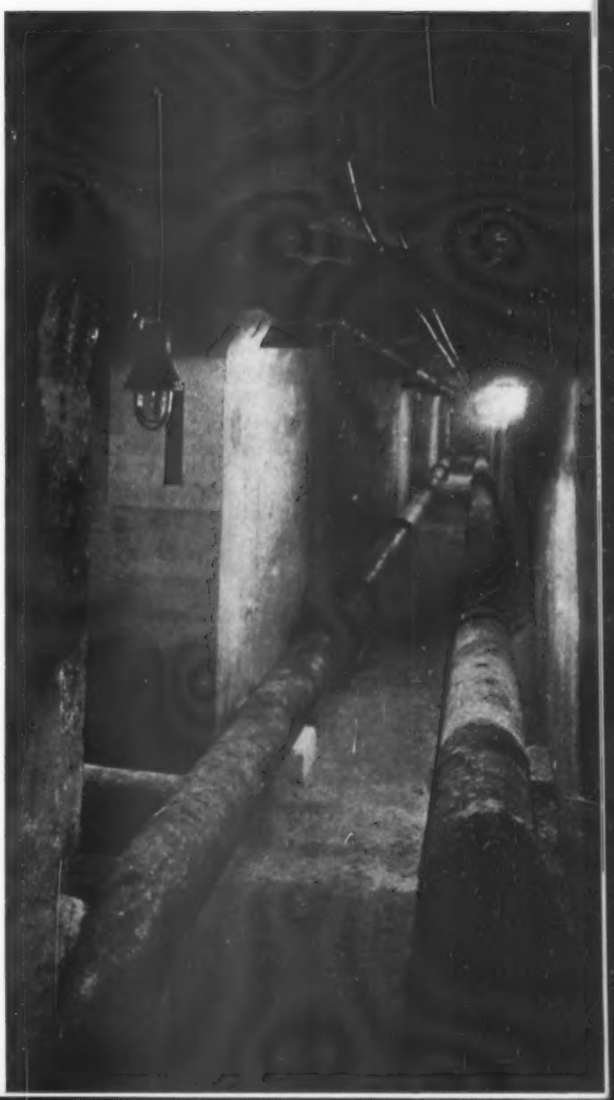
whereas with naphtha reversion, it is possible to go up to 79 octane, A.S.T.M. The limit on octane seems to be the physical deposition of coke in the coils.

If a single coil naphtha reversion is considered, the economics are very bad due to low conversions on the added gases, propane and butane. The more propane captured and recycled, the worse the situation becomes because of a drop in gasoline production per pass. If the pressure is lowered and the temperature increased, a start is made to remedy the defects of naphtha reversion. Larger percentages of the C_3 and C_4 components are converted and this cuts down the recycle and recovery costs, etc. For octane levels comparable with those produced by catalytic cracking such as Houdry, reported elsewhere in this issue, the single coil reversion gives high conversions and approaches the aromatic type of thermal polymerization plant. It is quite generally accepted that a double coil naphtha reversion plant offers no advantages over the type plant combination when reforming and polymerization are carried on simultaneously, throwing the products into a common or separate fractionators.

When operating on East Texas naphtha of 50.0 API gravity, 250-440 deg. F. boiling range of 42 octane, it is average to obtain a 70 octane (butane-free) gasoline. By adding C_4 hydrocarbons usually available in a refinery, it is quite common to raise the octane level to about 72 for 10 lb. Reid gasoline. The yield is around 75 percent maximum on the reforming operation. It is well to keep in mind that no reforming process yet developed, which produces 70 or better octane, will yield less than 20 percent gas or more than 75 percent gasoline by volume. It is an interesting fact that the reformed product, before blending with the more volatile C_4 cut, is slightly lower in gravity than the charge stock. This is true regardless of whether it is reformed under 250 lbs. or 1,000 lbs. pressure. This fact indicates, without any other data, that we are really transforming paraffins (high API gravity) to ring type (low API gravity) hydrocarbons. This is true in spite of the fact that considerable volatile material is produced and is in the reformed gasoline. The high pressure operation results in more tar formation and less gas as would be expected.

POLYMERIZATION

In speaking of the thermal polymerization of gases, enough experimental work has been done to justify the conclusion that C_3 and C_4 compounds are the materials undergoing change. The original thermal polymerization plant installed by the Pure Oil Company had for its object production of gasoline by polymerizing unsaturates already in the Gyro and other cracking still gases. It was soon found that the reaction was



Courtesy U. S. Navy Recruiting Bureau

Naval airforce consumption of iso-octane represents a significant and growing figure.

not quite as simple as adding one propylene to one butylene and obtaining a heptylene boiling in the gasoline range and possessing a relatively high octane value. When the data were carefully checked it was found that a yield of over 100 percent of the unsaturates was obtained as a liquid and, barring a miracle, this meant that considerable percentages of saturates had been converted to liquid polymer gasolines.

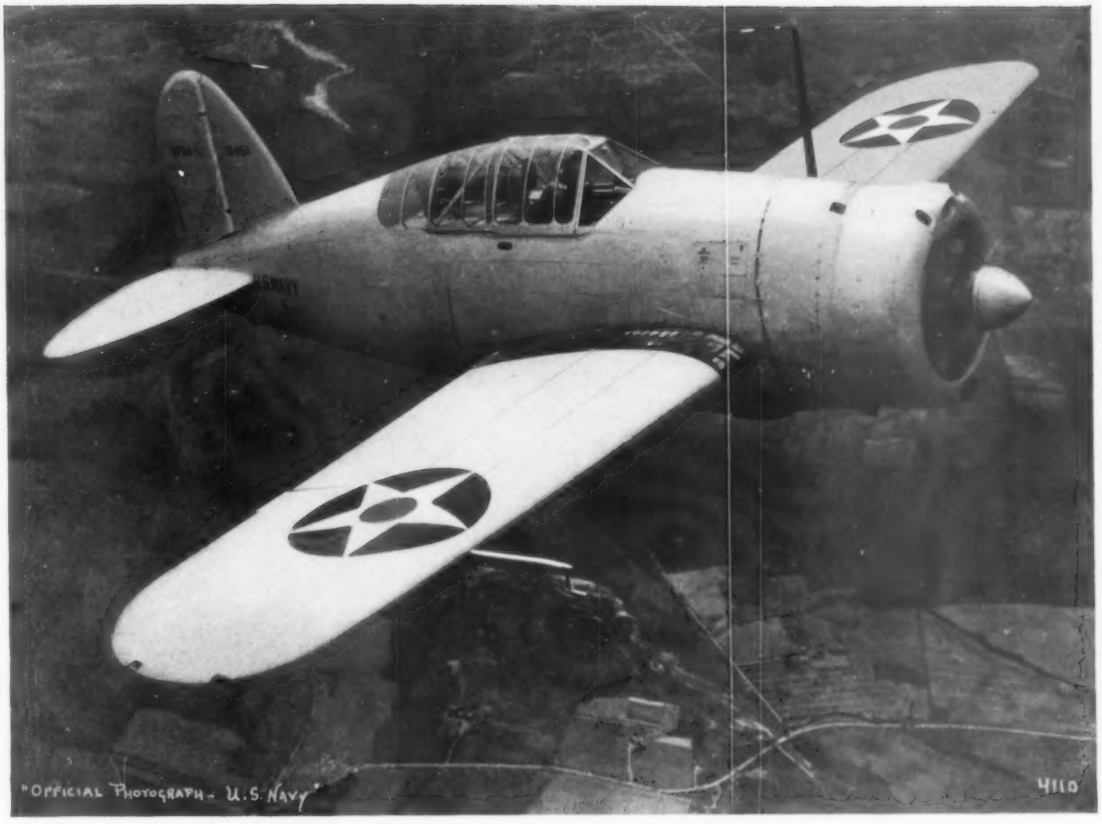
The outgrowth of this pioneer work of the Pure Oil Company, under the guidance of Dr. Wagner, was to develop two processes of polymerization. These have been fully described before the A. P. I. at Los Angeles in November, 1935 and elsewhere. They are the high pressure-low temperature system for the production of maximum yield of liquid polymer blending condensate and the low pressure-high temperature aromatic producing type of plant wherein a lower volumetric yield of polymer is obtained. The high pressure condensate is about 75-85 octane (neat) and the aromatic is around 88-90 (neat) octane. The first product is largely olefins whereas the aromatic condensate is above 80 percent aromatics with very low olefin content. Examples of both type plants have been put into commercial operation on a wide scale. (Not very many aromatic plants have gone into operation but the interest in them is at a peak at present.)

A few general observations may be of interest in connection with high pressure polymerization. If the reaction time is held at a constant by raising the pressure, more liquid per pass at any given temperature is produced. This is logical because the process is a condensing (chemically speaking) operation in which the end product occupies less space than the gaseous charge. The reference here is specifically to propane and butane as charge stocks. The higher the pressure and temperatures, the greater is this difference. By raising the pressure, it is found also that less ethane, ethylene, and methane are obtained when making a constant liquid production per pass. There is, however, a debit side of the ledger as regards the effect of pressure in polymerization. It is unfortunate that octane decreases with increase in pressure and this is a point that cannot be ignored. This is one reason why commercial poly plants producing polymer for gasoline blending purposes have dropped off in pressure to around 600-700 lbs. whereas it was planned a few years ago to operate in excess of 1,000 lbs.

Mention should be made of the introduction of catalytic polymerization plants as exemplified by the Dubbs phosphoric acid plants. These plants have found a ready market due to the fact that they serve the industry in the role of cream skimmers and are profitable to operate. They are also cheap to install and give satisfaction. The catalyst appears to play the part of a true catalyst or at least a semi-catalyst. The phosphoric acid really produces an intermediate compound with the unsaturated hydrocarbons which is short lived and breaks down after uniting two molecules of unsaturated normally gaseous hydrocarbons. It carries on at temperatures of 200-400 deg. F. lower than are required for the polymerization of two unsaturates by purely thermal means. The product appears to be of the same chemical constitution as the thermal polymer; it is composed largely of olefins of approximately double the molecular weight of the gas from which it was made.

The economics of polymerization depend to a great extent on the availability of a quantity of cracking still gases or a cheap supply of propane and butane which can be first pyrolyzed into unsaturates which become raw material for the poly operation. On the other hand, reforming can be carried on best in conjunction with a poly plant for if the maximum octane from a low octane naphtha is to be obtained it is preferable to operate at high temperatures and this is conducive to unsaturated gas production. In order to operate at high temperatures it is usually impossible to show an economical operation if no provision is made to convert the liberated gases back to saleable liquid products such as gasoline. At present market prices, poly plant operation without a gas plant may be expected to pay out in a period of 18 to 24 months.

The introduction of catalytic cracking processes such as Houdry has changed the above set-up in some respects. The Houdry converts its liberated or nascent unsaturated gases to liquid *in situ*. This is true no matter whether reduced crude oil or naphtha is charged. Other catalytic processes have been mentioned lately. These processes are of two distinct types but both are catalytic. The one considers charging gas oil boiling range feed stocks with the aim of producing a high yield of relatively high octane gasoline once through and producing a high yield of furnace oil as a by-product. Results reported indicate that 35-40 percent of catalytic cracked gasoline can be produced from a gas oil charge stock in one pass. It is generally assumed now that it is more economical in most cases to crack the cycle stock (or furnace oil) in thermal units. This appears logical for the reaction of catalytic cracking is one wherein the catalyst has a definite influence in converting paraffin to ring compounds such as naphthenes and aromatics. If this major assumption be true, then why should anyone even contemplate passing reacted material



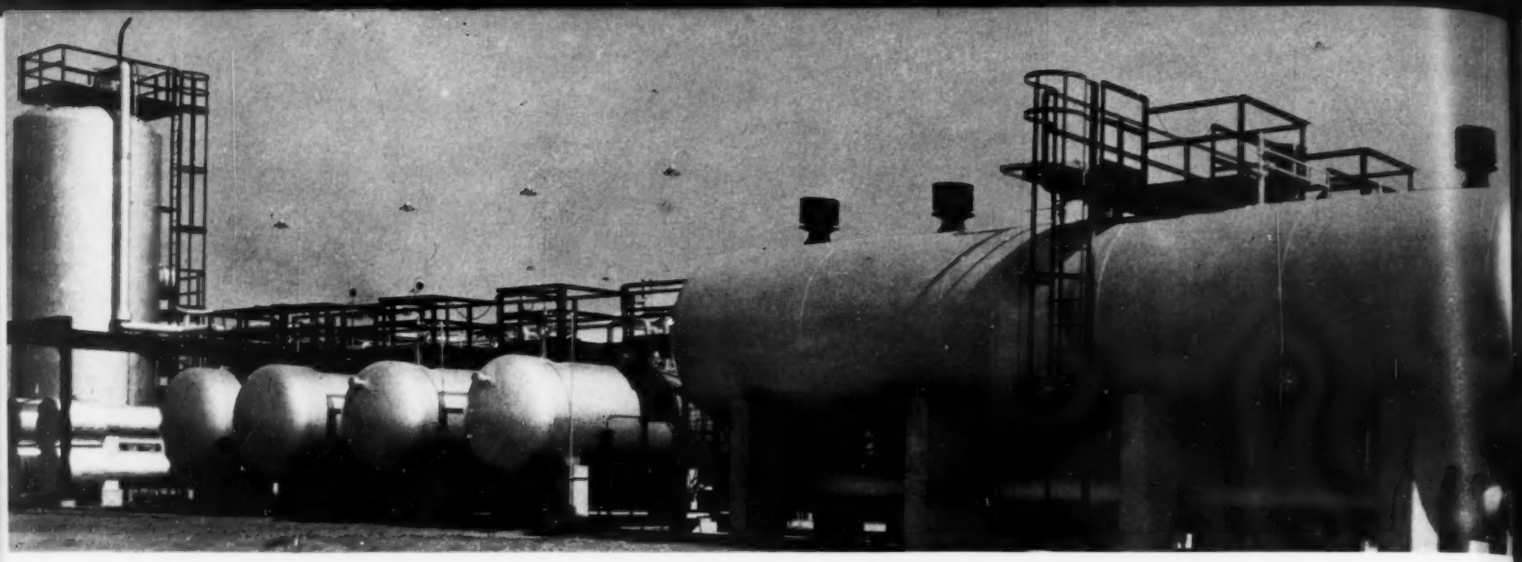
Iso-octane permits performance well in excess of 300 m. p. h. for this Brewster F2A-1 single seater navy fighter. Photograph, courtesy S. R. Thompson of A. E. Brewster Aeronautical Company.

through the same catalyst again and hope to change the ring cycle stock back to paraffins or to other low boiling hydrocarbons in the gasoline range? It seems fundamentally sound to subject such cycle stock to heat to break down the ring type structure to lower molecular weight hydrocarbons.

This high octane gasoline question was first answered by making aviation gasoline by a sort of cream skimming operation; by segregating the volatile, low end point straight run naphthenic gasoline from selected crude oils. The Ethyl Corporation made possible a large increase in octane by use of their tetraethyl lead mixture. While the aviation gasoline of 10 years ago was only 74 octane, it was quickly raised to 80 then 87—all by the use of lead and employing refinery technique to give the proper distillation range, freedom from gum and sulphur content. The first serious attempt really to raise the octane of great quantities of aviation fuel appears to have derived from work by the Shell Oil interests. The production of commercial iso-octane was first practiced by this pioneering company. This product is a chemical one and depends upon the production of large quantities of cracking still gases which in turn depends upon large quantities of oil being cracked each day. The gases, butane and butylene, are separated from the other gaseous constituents as a cut called a B-B cut. It is well known that the butylenes are made to unite with each other by means of a catalyst such as phosphoric acid or by sulphuric acid and they form a light carbon unsaturate, diisobutylene. This is then subjected to hydrogeneration with the proper catalysts and iso-octane results. The cost per gallon has been decreased from 50 cents to around 30 cents by technical developments. This material is 93-96 octane and is a very desirable blending agent for aviation gasoline. The only bad feature of iso-octane is the lack of large quantities at a reasonable cost. Since the raw material is butylene, and one barrel of crude oil under normal refinery conditions yields less than two percent of butylene by weight, the production of really large volumes of iso-octane as a by-product of other refining operations is not feasible. This material has been so good, however, that research and development has been stimulated to a high degree to find other materials of similar qualities. One direct result has been the greater interest shown in the installation of alkylation plants. This process produces a 92 octane alkylate from butylenes and isobutane, the latter product coming not only from refinery gases but also from the natural gasoline industry. By pyrolysis of butane about 40 percent isobutane can be made available as an alkylation raw material. By pyrolysis of the same raw material, normal butane, under different conditions there can be obtained the butylenes. Since butane has been available in abundance, the prospects for alkylation appear at least as bright as those for iso-octane did three years ago. There are already a dozen plants in operation.

These two tailor made aviation fuels, or blend stocks have been the backbone of modern high speed long distance aeroplane operation during the past two years or so. Great sums of money have been expended and more is contemplated. The one restraining factor in the continued installation of the iso-octane and the alkylation plants is the fear of a newcomer in the field—it is called catalytic reforming and if conducted in the presence of hydrogen is called hydroforming.

The entry of the Houdry catalytic cracking process into the field of aviation fuel production has stimulated research and development along the lines of catalytically decomposing heavy hydrocarbons into aviation gasoline like materials. It is worthwhile to note that this system is the opposite of the iso-octane and alkylation processes because they unite two molecules to give aviation gasoline hydrocarbons. Scientists are now trying to establish the minor secrets of these reactions but no past set of rules has so far been established as to the exact reactions taking place. This problem is much more complicated than the synthesis of iso-octane or the production of alkylate from butylene and isobutane. The product of catalytically reforming paraffine naphtha appears to be about 80-82 octane and can be leaded up to 90-92 octane aviation fuel. The potential quantity of aviation gasoline from the catalytic reforming of naphthas is so very much larger than the potential iso-octane and alkylation gasoline most of the industry is either conducting experiments in this direction or it is on the verge of installations. The product ranges from 86-92 octane and can be leaded to 100.



COLD ACID Treatment of Cracked Distillate

Stratcold Treating Plant of Richfield Refinery Effectively Reduces Sulphur Content in Heavy Distillates from California Crudes.

AMONG the most modern and complete refineries in the United States is the great plant of Richfield Oil Corporation at Watson, California, which was constructed during 1938 and which was described in detail in WORLD PETROLEUM in March 1939. It includes two large combination units each capable of handling a charge of 25,000 bbl. per day, cracked distillate finishing units, a polymerization unit and other features of a complete refining plant.

Since the refinery is engaged in producing cracked distillates from California crudes it was confronted with the problem of controlling economically the sulphur content of this material. As a step toward the solution of this problem it was decided to add a Stratcold treating plant for the cold acid treatment of the higher boiling portion of the distillate to give the desired overall sulphur reduction.

In the stabilization process the cracked distillate is debutanized and fractionated into a light and a heavy cracked distillate. The sulphur compounds in the light cracked distillate are satisfactorily removed by caustic washing; while the heavy cracked distillate, having a boiling range of from 220 deg. F. to 400 deg. F. and containing sulphur compounds more difficult to remove, is processed at the Stratcold treating plant. The acid-treated distillate is redistilled, blended with the caustic-washed light cracked distillate and sweetened before being used in the finished gasoline blend.

The Stratcold acid treating process employed, consists essentially of contacting the raw distillate with clean 98 percent sulphuric acid under precisely controlled temperature conditions in a three-stage, counter-current treating system. The treated distillate is then passed through a clarifier, a two-stage water wash system, and is contacted with caustic soda for neutralization.

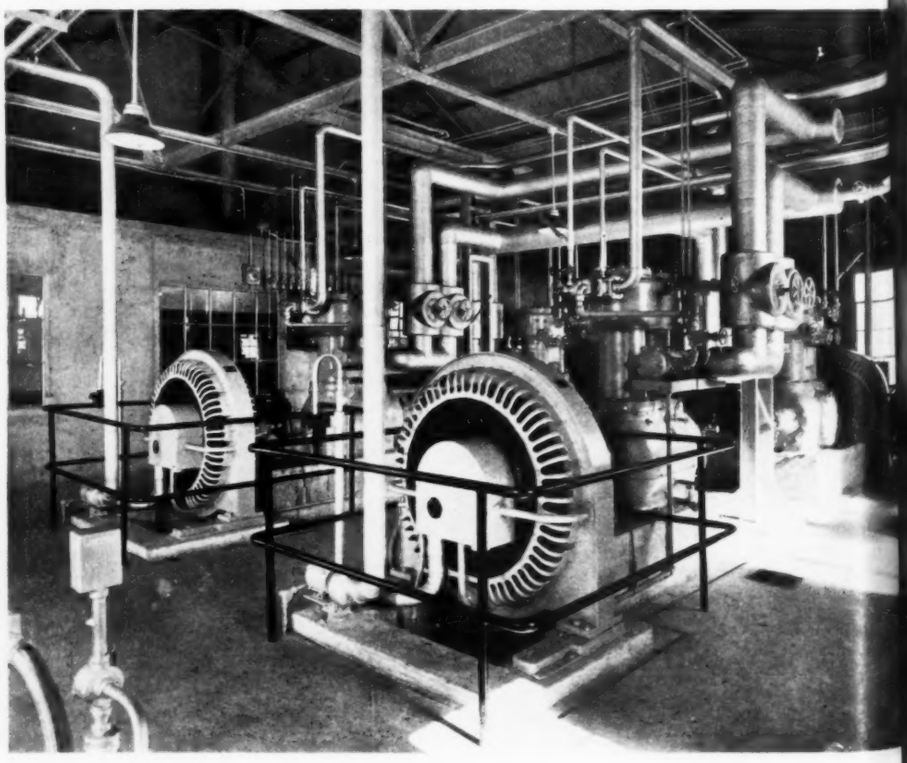
The plant has sufficient capacity to treat 11,000 bbl. per day of cracked naphtha distillate with nine pounds of 98 percent sulphuric acid per barrel of distillate and to maintain treating temperatures at the first, second and third stages of 30 deg. F., 30 deg. F. and 20 deg. F.

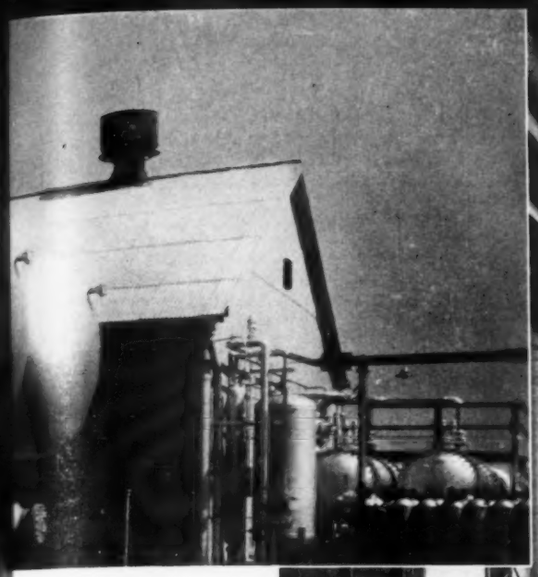
The Stratford Engineering Corporation designed and constructed the plant. The contractor worked closely with the refinery's engineering department in planning the plant so that the final design incorporates the company's standard construction practices.

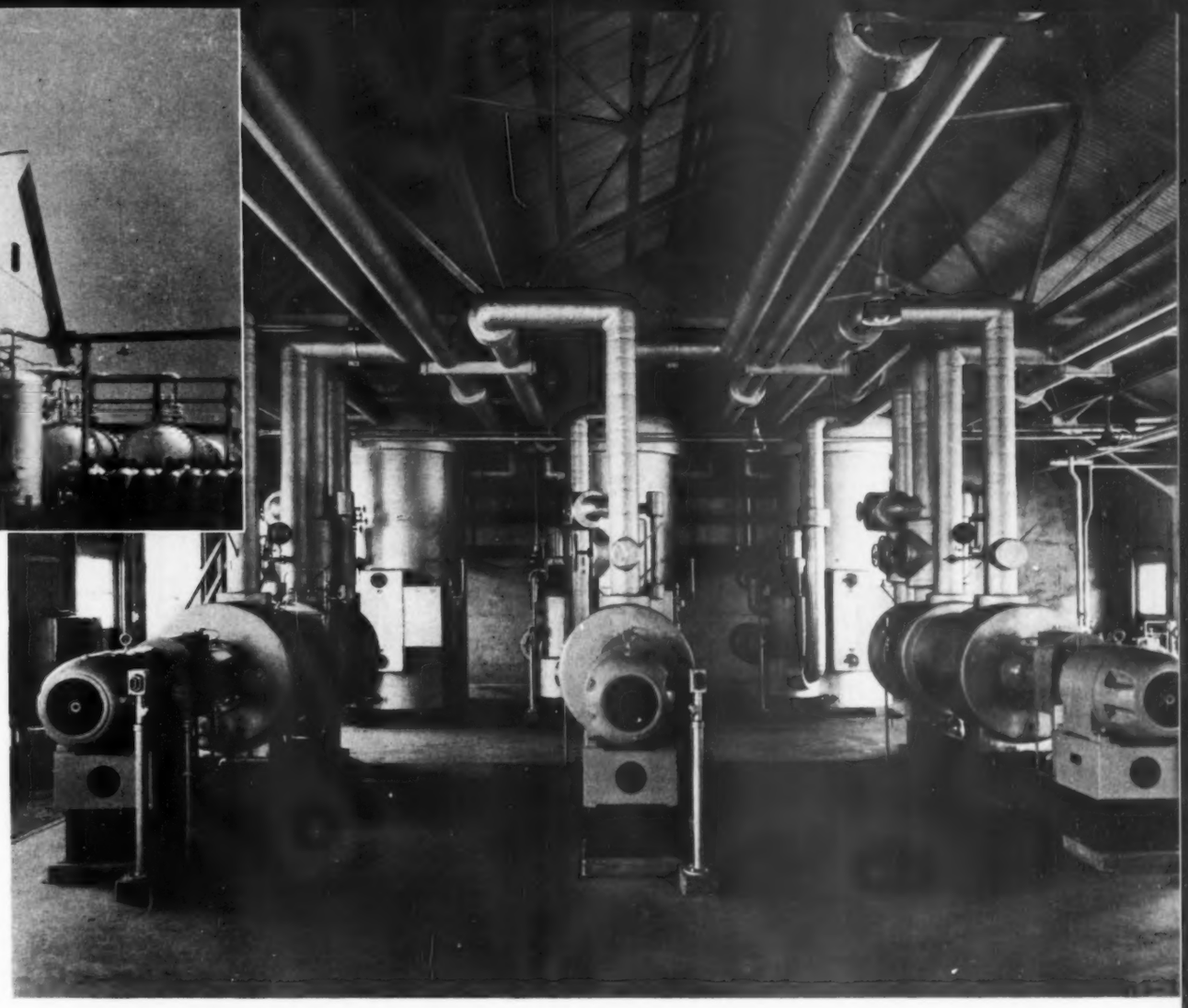
EQUIPMENT

Each stage of the treating process is provided with a chiller and contactor. The distillate chillers of the shell and coil type, cool the distillate to the desired contacting temperature by circulating liquid ammonia over the chiller coils. The distillate is intimately mixed with the acid at each stage with a Stratco horizontal refrigerating contactor equipped with an ammonia cooling head for temperature control and absorption of the heat of chemical reaction.

Refrigeration room showing four synchronous motor driven York ammonia compressors.







Right, pump room and above exterior view of the Stratcold cold acid treating plant of the Richfield refinery at Watson, California.

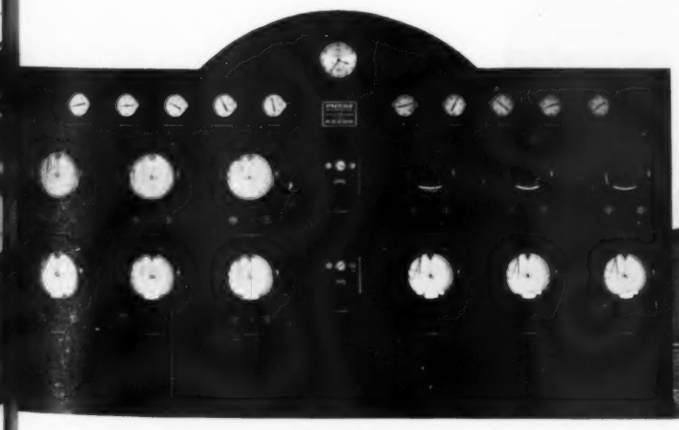
All settlers are of the decelerating type designed for a working pressure of 80 lbs. per sq. in. The initial water settler, sludge settlers and soda settlers are steel vessels designed and constructed in accordance with the API-ASME Code for unfired pressure vessels with ⅛ in. corrosion allowance. The two water settlers and their immediate lines are constructed of Everdur Bronze for handling the corrosive weak acid solution encountered at this stage of the processing. Corrosion allowance for these vessels is 1/16 in.

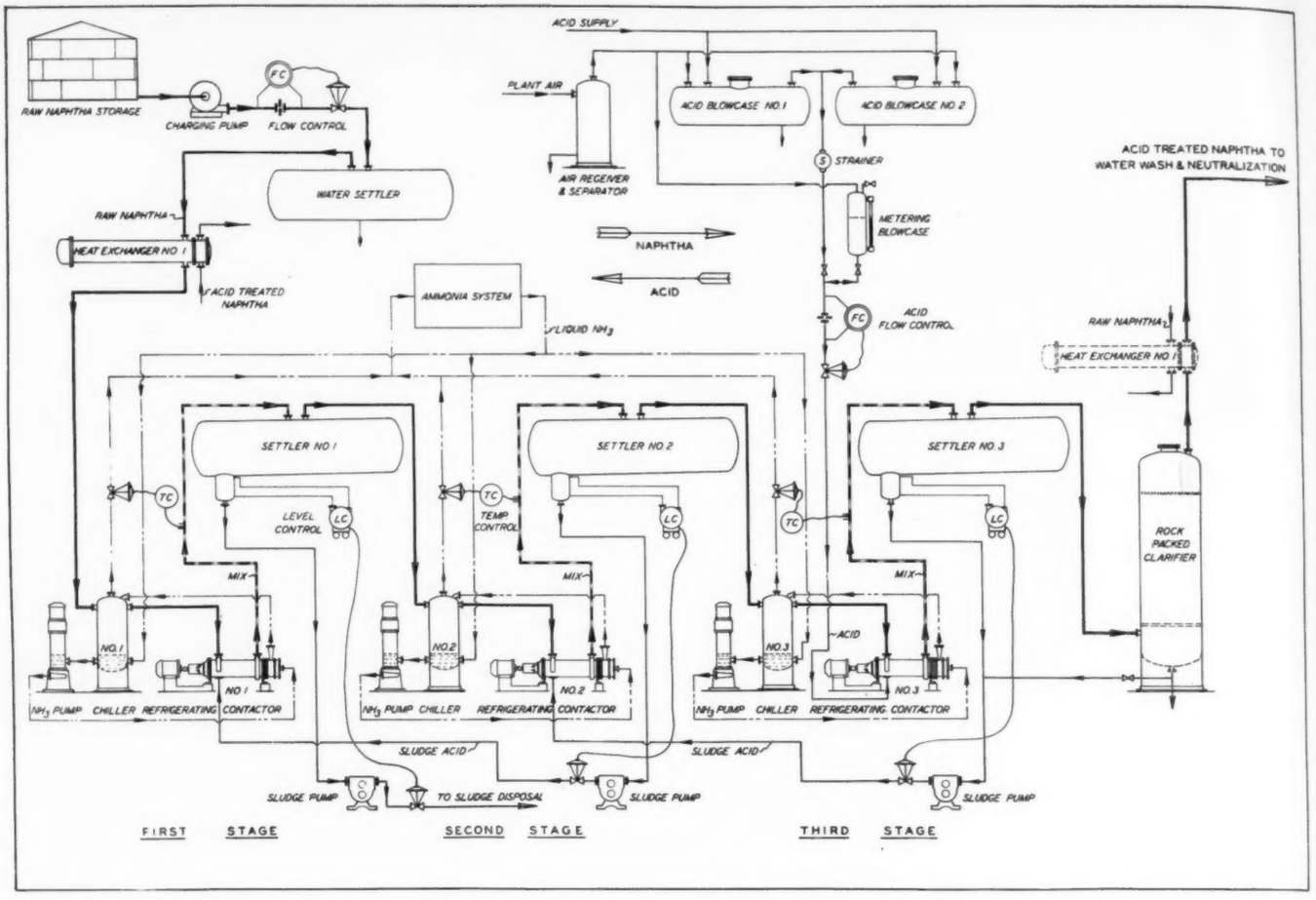
Acid particles entrained in the distillate leaving the third stage settler are coagulated in a rock packed clarifier tower and returned to the second stage contactor.

Centrifugal type pumps are used for charge, booster, water booster and soda services. A Stratco standard horizontal high-dispersion contactor is used to contact the water washed treated distillate with caustic soda for neutralization. Orifice plates provide mixing for the water washing of the treated distillate.

Positive displacement type pumps are used for handling the acid sludge from the sludge settlers; pressure regulators on the pump by-

Below, control panel board in a Stratcold plant, and right, side view of the plant showing acid-distillate settlers.





Above, flow diagram of a Stratcold treating plant, and page 83, arrangement of the equipment.

pass lines maintain a constant discharge pressure to facilitate the smooth performance of the liquid level control equipment for the sludge settlers.

The load on the refrigeration system is reduced by the use of heat exchangers to transfer excess heat from the raw feed to the cold acid treated distillate. This exchange brings the temperature of the raw feed to within about seven degrees Fahrenheit of the treated distillate temperature. All low pressure ammonia lines, ammonia chillers, refrigerating contactor shells, cold oil lines, sludge settlers, sludge pumps, the rock packed clarifier and oil heat exchange equipment are covered with a heavy vegetable cork insulation.

CONTROL

Instrumentation of the unit is very complete and results in the operation of the unit largely by automatic control equipment.

Recording flow controllers are provided for the distillate and acid feed to the treater. Recording flow meters measure the water used in each stage of the water wash and the quantity of caustic soda being circulated for neutralization.

The temperature of the distillate-acid mixtures leaving the three contactors is controlled by recording temperature controllers.

Differential averaging type level controllers maintain uniform sludge levels in the settlers at any desired point in the vessel.

Recording pressure and differential meters give a record of the liquid ammonia circulation from the chillers and allows the operator in the treating section of the unit to know at a glance whether more or less capacity is desired from the ammonia compressors. Each chiller is equipped with a level controller for maintaining a constant level of liquid ammonia within the chiller; non-frosting sight glass level indicators provide a visible check on the ammonia levels. Air and other non-condensable gases are continuously removed from the ammonia circulating system by an automatic non-condensable gas separator.

A pressure controller on the suction of the booster pump prevents pressure surges through the distillate chillers, contactors and sludge settlers. Pressure regulators maintain a uniform air pressure for the acid blow cases and instrument operation. A two-stage, air cooled 45 CFM motor-driven air compressor supplies the treater requirements, although the plant air supply may also be used.

The unit is amply provided with pressure gages and thermowells for routine checking of the unit's operation.

Pressure relief valves on both the refrigerating and treating equipment give protection from high pressures.

YIELD AND TEST

The following tabulation presents yield and test data taken at the Richfield Watson plant.

YIELD DATA

Acid Rate: Lbs. of 98 percent Sulphuric Acid per bbl. of Feed....6.64

Temperatures:

1st Stage	30 deg. F.
2nd Stage	30 deg. F.
3rd Stage	20 deg. F.

Capacity and Losses:

Feed, bbl. per day	11,329
Trtd. Dist.	96.27%
Net Yield, 400 deg. EP Trtd. Dist	93.05%
Treating Loss	3.73%
Polymerization Loss	1.81%

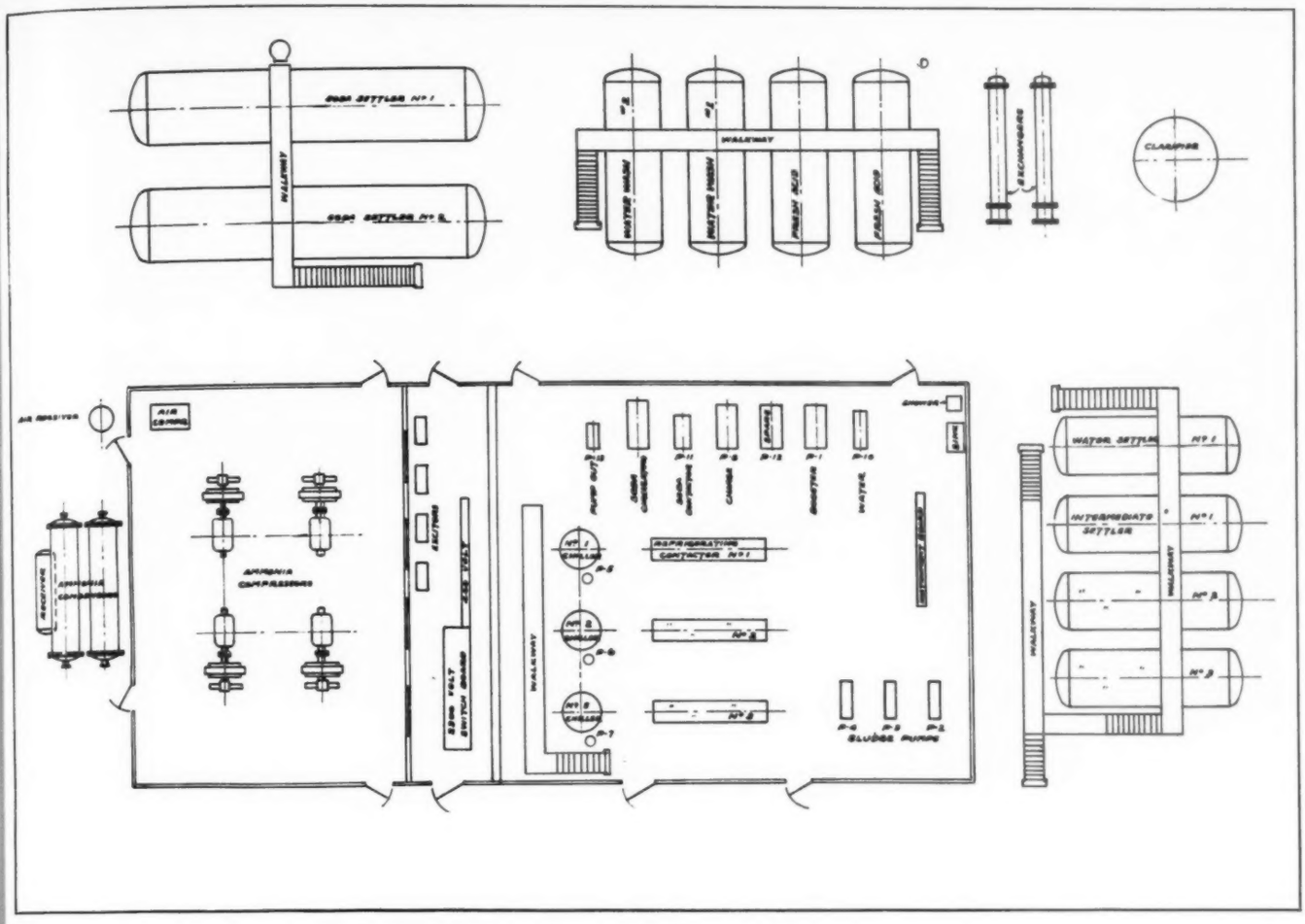
LAB. DATA

	IBP	EP	Per-cent 400 EP	Per-cent S	C.D. Gum
Raw Feed	217	414	98.4	.631	
Trdt. Distillate	217	478	96.7	.423	
400 deg. E. P. in Feed	217	400		.614	146
400 deg. E.P. in Trtd. Dist.	217	400		.248	5

The distillate is cooled in the chillers and contactors by the vaporization of liquid ammonia; the ammonia vapor is then compressed and condensed for recirculation.

Four vertical, two-cylinder, ammonia compressors driven by synchronous motors are provided for compressing the ammonia vapors

(Continued on page 83)



for the subsequent condensation. Normally two compressors are operated on the third treating stage where the greatest heat liberation in the treating reaction occurs; one compressor provides the capacity required on the first and second stages, leaving the fourth compressor as a standby. Each compressor may be operated at one-third, two-thirds, or full capacity, giving ample adjustment for an economic operation with varying load requirements. Power requirements for the ammonia compressors average approximately 0.9 kilowatts per barrel of distillate treated.

ELECTRICAL

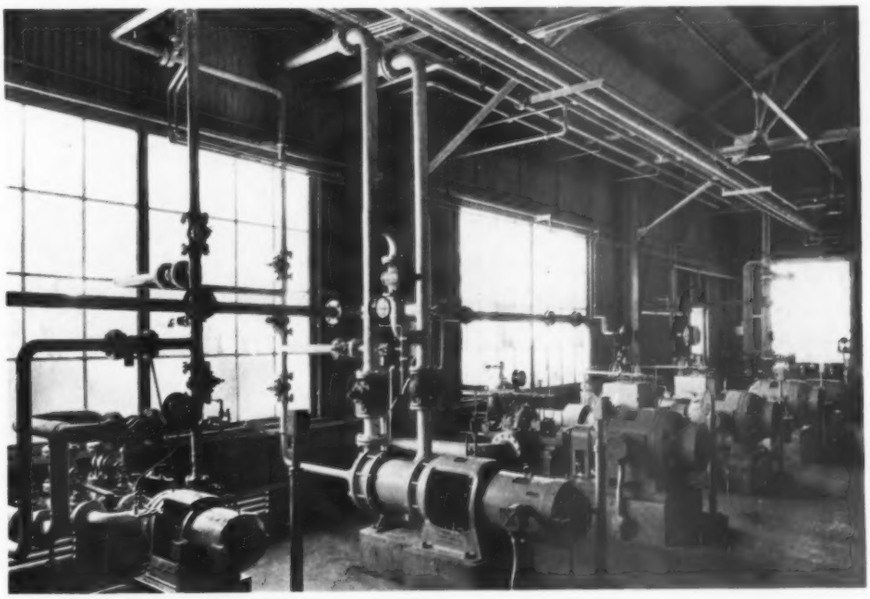
The contactors, air compressor and all pumps with the exception of the pumping-out pump are driven by 440-volt explosion-proof induction motors. The ammonia compressors are driven by 2300-volt synchronous motors, provided with fresh air circulation through the collecting ring enclosure to make them explosion-proof; the air circulation system for the individual motor must be put into operation before the motor can be started; and, in the event that the air fan fails, the synchronous motor is automatically stopped. Explosion-proof start and stop buttons are installed in the immediate vicinity of all motors.

The switchboard room contains all electrical equipment which is not of explosion-proof construction. Inflammable gases are prevented from entering this room by maintaining a pressure slightly above atmospheric on the interior by forcing fresh air into the room with a blower type fan located at the roof section of the building.

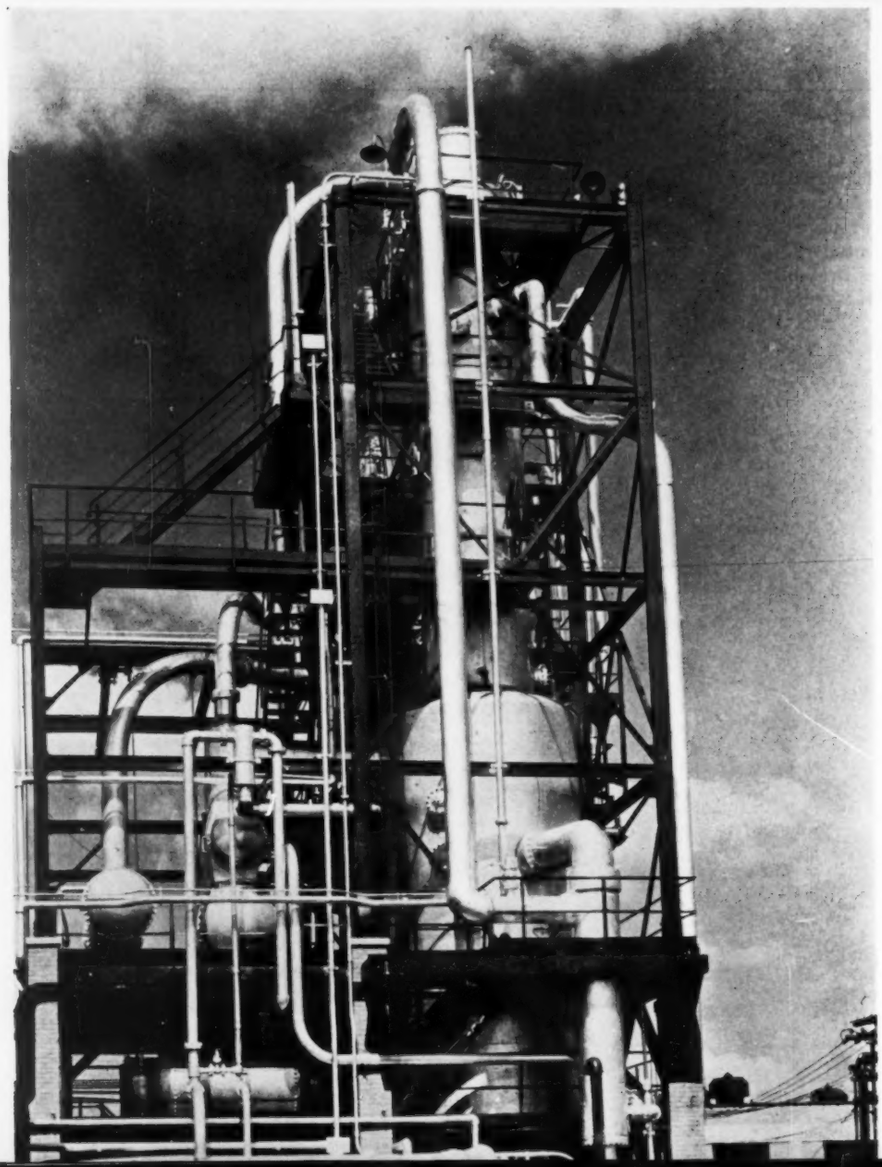
The switchboard contains panels systematically arranged for the 2300-volt incoming power, the synchronous motor-starting equipment, the 440-volt incoming power and 440-volt starting equipment.

Lighting fixtures and conduit fittings in the treating room, refrigeration room and out of doors are of the vapor-proof type. Localized lighting throughout the unit provides adequate illumination.

Soda pump, soda contactor, charge and booster pumps and standby.



SCIENCE OF INSTRUMENTATION Keeps Pace with Growing need for Automatic Control



THE increasing use of automatic control is inherent in mass production industries, such as oil refining. Consistent operation with its resultant uniformity of product quality is necessary because the economies of large throughput may be more than offset by intermittent error. Accordingly, the policy of Imperial Oil Limited has been to use automatic controls to the greatest degree possible, both in the new and the existing units in its refineries.

Automatic control of process units has been established on the basis of two fundamental concepts of manufacturing: first, that smoothness and stability of operation are essential for high quality and maximum yield of products; secondly, the complexities of modern oil refining equipment entail so many variables that manual control is impracticable because of the many individualities that would be involved. In addition, the complete control of any unit for satisfactory co-ordination must be centralized where visual indications and records of all process factors are available to the chief operator.

Two recent installations in the Sarnia Refinery of Imperial Oil Limited, among the many automatically controlled units of that company, indicate the extent to which this policy is being followed. In the construction of their grease plant, the latest type of con-

Above, central control room of the solvent dewaxing plant, and left, fractionating towers of the solvent recovery system at Sarnia.

Control board of the grease plant at the Sarnia refinery.

trol equipment has been installed in keeping with the progressive developments in the methods of grease manufacture. Precision control of the quantities of solid components used in producing soaps is secured by weighing the materials on a special type weigh-lorry located on the kettle charging floor. All other steps in the operation of the grease kettles in the Sarnia plant are controlled from a central panel. From this panel and without leaving the operating floor, the attendant can charge to any kettle any of the various liquid components entering into the manufacture of greases. All materials delivered to the kettles are metered and the quantity of the individual components is automatically regulated by means of a shut-off device on the individual meters, which cuts off the flow when the correct amount has been charged. The temperature of the kettle is indicated and recorded on the panel and automatically changed during the processing cycle as required for the particular type of grease being produced. Although the manufacture of grease is a batch operation where the number of process variables are relatively few, continuous and accurate control is essential for the maintenance of high quality and maximum plant throughput. These results have been realized in the actual operation of the Sarnia grease plant and, in a large measure, are attributed to the automatic control features.

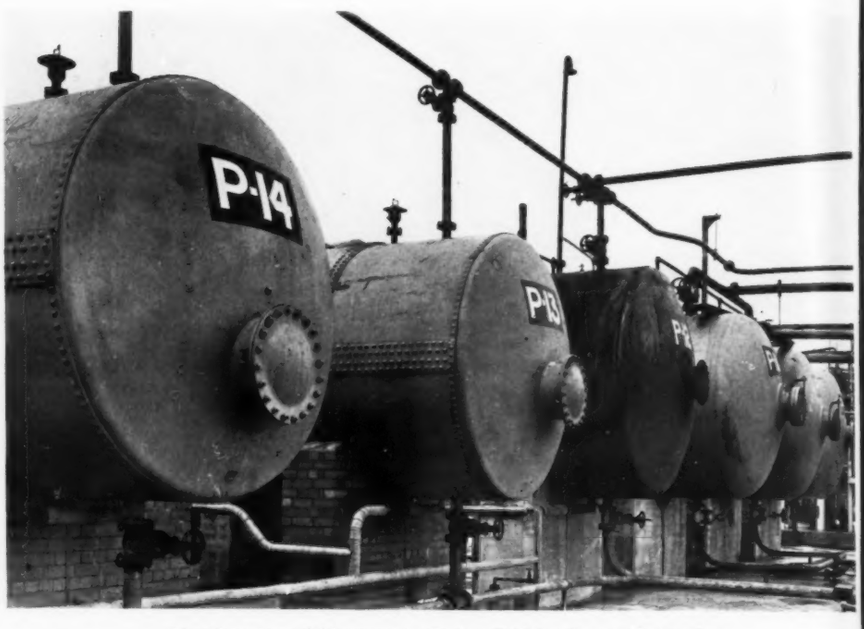
The control installations in the new Ketone Solvent Dewaxing plant at the Sarnia Refinery are of a much more complex nature. In this plant there are, in addition to the refrigeration unit required for the chilling operation, four independent, although inter-related, processes. First, the mixing of the waxy oil with the correct solvent volume and the chilling of the mixture to the required temperature for wax separation; secondly, the filtering of the wax from the chilled solution; the third and fourth interdependent steps are simultaneous recovery of the solvent from the oil and wax phases discharged from the filter. Since all these operations must be co-ordinated and synchronized, the complete control is centralized and is automatic to the greatest degree possible.

One of the most important phases of the process is the filtering of the wax from the solvent oil solution, and it is imperative that the wax crystals be of uniform type and proper size for satisfactory filter operation. This requires that the ratio of solvent to oil be constant at all times and that the chilling during the initial period of the formation of the wax crystals be conducted at a specified and uniform rate. Suitable flow control equipment of the waxy oil and solvent streams automatically maintains the desired characteristics of the solution, and the chilling is controlled to the desired uniform rate by means of flow controllers on the solution feed and the chilling medium. Precision operation of the two distillation units which recover the solvent from the oil and wax is maintained by means of flow controllers on the charge and furnace feed circuits, and by automatic control of temperature, pressure, and liquid levels at the essential points in the fractionating systems. This control has resulted in a negligible loss of solvent when recovering it from the oil stream and from the wax stream.

The necessity for automatic control of manufacturing processes is, in general, recognized by both the management and technical personnel in many manufacturing industries. With this impetus, instrument manufacturers have made, and are making, a constant effort to devise and improve control equipment to meet the many applications involved. The illustrations accompanying this article indicate the importance that Imperial Oil Limited is placing on modern instrumentation to obtain centralized automatic control of its manufacturing operations.

WORLD'S REFINING Facilities Respond To War's Influences

Capacity to Supply Increased Demand Exists in Western Hemisphere — Industry in Belligerent Countries Placed on a War Footing — Progress in Installation of Specialized Processes.



Liquid propane field storage tanks in a British solvent refining plant.

CHANGES IN supply sources and trade routes caused by the war in Europe have directed renewed interest and attention not only to available supplies of crude oil but also to the location and capacity of refining plants which must be depended upon to process this crude into various petroleum products. Of the belligerent nations neither Britain nor Germany has refining facilities adequate to supply its normal commercial requirements. France is somewhat better equipped in this respect. Its twenty plants have a total crude capacity of roundly 6,500,000 metric tons of crude annually but this capacity never has been fully employed and the country has been a regular importer of considerable quantities of gasoline, gas oil and other products under peace conditions. Germany's established facilities enable her to refine something over half her annual crude requirements while the United Kingdom can process considerably less than half her peacetime needs.

Even though these countries possessed more extensive refining facilities than they now have these would hardly serve to meet increased wartime demands which are concentrated on a relatively few products of which gasoline, fuel oil and lubricating oil are the most important. Because of this and because of the saving in cargo space and domestic labor the importation of finished products rather than crude offers definite advantages under war conditions.

A survey of the world refining situation reveals that the total daily crude capacity of all plants is roundly 7,500,000 bbl. Of this approximately 60 percent or 4,500,000 bbl. daily capacity is in the United States. This division appears a logical one since this country provides about 60 percent of all crude production. As a matter of fact, however, refining facilities during the past few years have been expanding more rapidly outside the United States than inside. Of the three largest refineries in existence at the present time two are located in South America and the third in Asia. The trend of the time seems to favor the location of refineries at or near the source of crude supply and the great increase in production in northern South America, the Near East and the Far East is being accompanied by a corresponding enlargement of refining capacities in those quarters.

According to statistics compiled by the U. S. Bureau of Mines the number of refineries in the United States at the beginning of 1939 was 558 of which 463 or 81 percent were in active operation. Total crude capacity was 4,456,620 bbl. daily and of this 4,186,555 bbl. or nearly 94 percent was actively employed, indicating that of the plants closed down the larger number were of small capacity. About half the operating capacity or 2,107,025 bbl. represented cracking equipment.

Since domestic demand for petroleum products in the United States, in terms of crude oil, is slightly over 1,100,000,000 bbl. yearly and since the capacity of active refineries, if fully employed, is nearly 1,500,000,000 bbl. it would seem that the American refining industry, if necessary, could supply 350,000,000 bbl. or 50,000,000 metric tons for export after conversion into products. Actually the exports of both crude and products average about half this quantity at the present time. There is, however, considerable surplus capacity that could be called into play to supply additional exports should the demand arise. In particular the new processes and equipment being installed for the production of high test gasoline make it possible for the United States to supply aviation fuel, one of the essential needs for war purposes, in substantial quantities.

In Europe the countries of greatest refining capacity are, in order, the Soviet Union, Roumania, France, United Kingdom and Germany. The rated capacity of Soviet refineries, a little over 600,000 bbl. daily, would be just about sufficient, if the plants operated steadily throughout the year, to handle the Soviet production of 200,000,000 bbl. of crude. Russia's principal products, however, are kerosene and fuel oil. These comprise the largest export items. The restricted facilities for the production of high test motor fuel and the rapidly growing internal demand for fuel oil appear to place decided limitations upon the quantity of these products that the Soviet Union can provide for outside markets unless an extensive revision and modernization of refining plants takes place.

Roumanian policy has favored the export of manufactured products rather than crude and the rated capacity of Roumanian refineries is well above the present crude production of the country. Some of these refineries are small and obsolete plants but those operated by the larger companies are thoroughly modern and efficient. Roumania, therefore, is the one country of Europe that can export a wide range of products up to virtually the full crude productive capacity

of its wells less the relatively small amount required for domestic use. In 1938 Roumania's exports amounted to 4,168,000 tons of which less than one percent was in the form of crude.

As previously noted France has sufficient refining capacity to cover peacetime requirements but actually has been importing products in considerable quantities each year. For the extra requirements imposed by the war it will be necessary to draw from outside sources. Great Britain and Germany are in a position to refine possibly 40 and 60 percent respectively of their peacetime needs but must import the remainder and all their added wartime requirements. Within the past two years Italy has greatly expanded its refining facilities but still imports 45 percent of its ordinary needs in manufactured form. The smaller European countries for the most part refine a portion of their petroleum requirements but also are importers to a greater or less extent.

The nations now engaged in war are precisely the ones who are the largest importers of petroleum products in normal times. To this demand will be added the needs arising from military and naval operations and both will have to be satisfied by importations.

WORLD'S REFINING FACILITIES
(Plants outside U. S. A.)
EUROPE

Company	*Plant Location*	*Daily Capacity (Bbl. crude)*
Belgium		
Belgian Cracking Co., S. A.	Langerbrugge-Evergem	450
Belgo Petroleum S. A.	Terdonck	1,250
Compagnie Belge des Gaz, Goudrons et Derives, S. A.	Forest	100
Compagnie Industrielle "Atlas" S. A.	Antwerp	1,500
Raffinerie Belge de Petroles	Antwerp	3,800
Raffineries & Distilleries Anversoises S. A. "Radian"	Antwerp-Kiel	2,000
Redeventza S. A. Belge Pour le Raffinage de Petrole	Petroleumpier, River Scheldt	3,000
France		
Brest Port Petrolier S. A.	Bay St. Marc	1,000
Cie. des Produits Chimiques et Raffineries de Berre	Berre	10,000
Cie. Financiere Belge des Petroles S. A. (Petrofina)	Dunkerque	1,400
Cie. Francaise de Raffinage	Gonfreville	16,000
Cie. Francaise de Raffinage	Martigues	8,000
Compagnie Industrielle des Petroles, S. A.	Frontignan-Cette	3,500
Pechelbronn S. A. D'Exploitations Minieres	Merkwiller-Pechelbronn	2,500
Pechelbronn-Ouest, S. A.	Donges	5,000
Raffinerie de Petrole du Nord	Port of Dunkerque	11,500
Raffinerie du Midi et Societe Immobiliere Industrielle du Midi Reunies	Balaruc-Les Bains	
Raffineries de la Vacuum Oil Co., S. A. F.	Notre Dame de Gravenchon	6,500
Societe Anonyme des Petroles Jupiter	Petit Couronne near Rouen	15,000
Societe Anonyme des Petroles Jupiter	Pauillac	8,000
Societe de Raffinage des Huiles de Petrole	Martigues-L'Avera	8,000
	Courchelettes nr. Douai (Nord)	5,000
Societe des Raffineries de Petrole de la Gironde	Bec d'Ambes	6,000
Societe Lyonnaise des Schistes Bitumineux	Auton	450
	St. Leger du Bois	150
Standard Francaise de Petroles, S. A.	Port Jerome (S. I.)	16,000

A. N. I. C. Refinery at Livorno, Italy.

Company	*Plant Location*	*Daily Capacity (Bbl. crude)*
Germany		
Benzin-und Oel-Industrie A. G. "Kagran" Vorm. Gustav Konig & Company	Kagran	
Bremer Chemisch Fabrik	Klaffenbach	200
Creditul Minier Oesterreichisch-Rumanische Petroleum-Vertriebs-Gesellschaft m.b.H.	Korneuburg	2,400
	Droesing	1,000
Danubia Aktiengesellschaft fur Mineraloel-Industrie	Regensburg	500
Deutsch Amerkanische Petroleum Gesellschaft	Templehof	600
	Dusseldorf	900
	Schulau Wedel	400
	Regensburg	350
Deutsche Erdoel Raffinerie A. G.	Misburg	3,000
Deutsche Gasolin A. G.	Emmerich	1,500
	Dollbergen	800
Deutsche Petroleum Aktiengesellschaf (D. P. A. G.)	Wilhelmsburg	1,100
	Hannover-Linden	300
Deutsche Petroleum A. G. Dpag Erdolwerke Wilhelmsburg	Harburg-Wilhelmsburg	
Deutsche Vacuum Oel A. G.	Oselbshausen, nr. Bremen	2,000
	Wedel, Holstein	700
Deutsche Viscobil A. G.	Berlin	100
Ebano Asphalt Werke, A. G.	Harburg-Wilhelmsburg	7,500
Erdol-Raffinerie Salzbergen G. m. b. H. (Ersag)	Salzbergen	600
Erdolwerke "Deutscher Adler" G. m. b. H.	Dollbergen nr. Hannover	
Europaische Tanklager und Transport A. G.	Hamburg	10,000
Farben, I. G., Leuna & Merseburg		9,500
Gewerkschaft Deutsche Erdolraffinerie Deraug	Misburg	2,600
Kohlenveredlung und Schwelwerke A. G.	Goelzau	
Kollner Benzin Raffinerie	Braunsfeld Koeln	100
Korneuburger Mineraloelraffinerie A. G.	Korneburg	2,400
Loeb, Max, Benzin-Benzol-Mineral Oelwerk	Koln-Braunsfeld	200
Mexas Kaltasphalta A.-G.	Neuendorf-Pirna	200
Mineraloel Benzin Fabrik	Ostermoor	500
	Worthdam, Hamburg	500
Mineraloel-Raffinerie Vorm, August Korff	Bremen	350
Mineraloel-und Asphaltwerke A. G.	Ostermoor, on Kaiser-Wilhelm Canal	2,800
Mineraloelwerke Albrecht & Co., Kommandit Gesellschaft	Wallhof	750
Mineraloelwerke Lichtenberg G. m. b. H. Komm.-Ges.	Lichtenberg	500
"Nitag" Petroleumhafen	Petroleumhafen	8,000
Norddeutsche Mineroloel A. G.	Dollbergen	200
Oesterreichische Fanto A. G.	Vosendorf, nr. Vienna	1,120
Pretschner Wagawa	Naudrof, Pirna	250

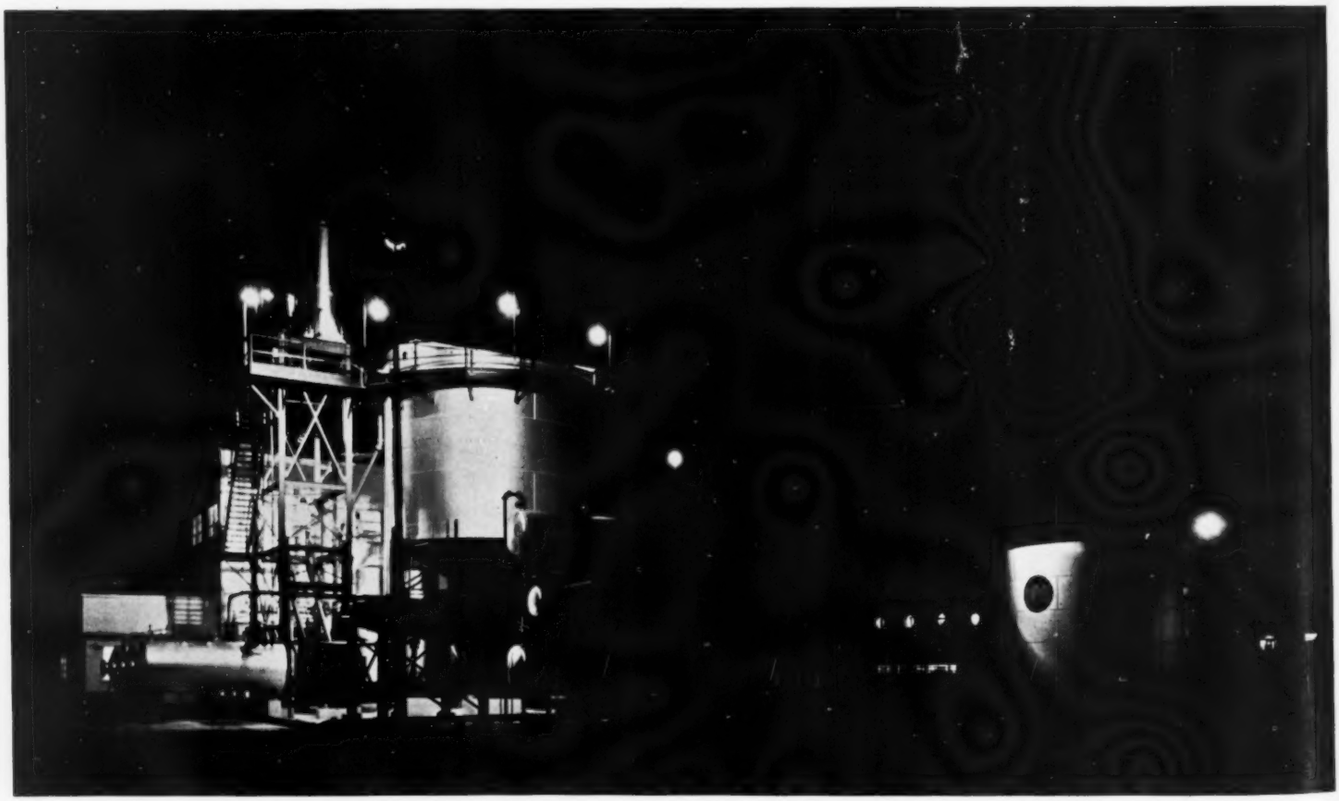
Since the only European country in a position to export petroleum products is Roumania, a substantial increase in imports of gasoline, fuel oil and lubricating oil from other parts of the world is to be anticipated as Roumania's available supplies are insufficient to meet the added needs of any one of the three warring countries.

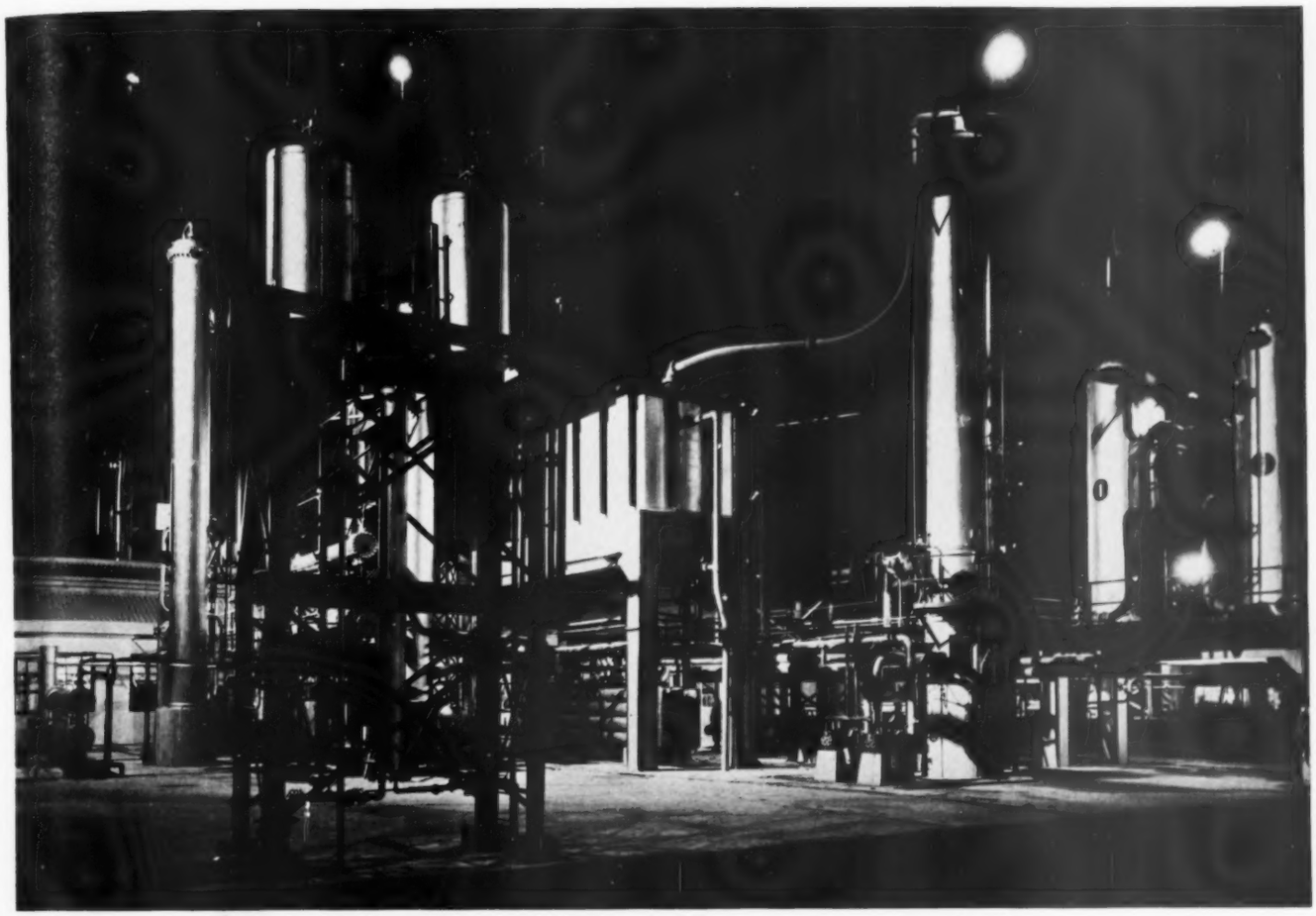
Egypt is the only country in Africa that produces oil in significant quantity. Egypt's two refineries process the local production and supply nearby markets but the continent as a whole is a large importer of oil on balance.

Moving eastward into southwestern Asia one comes to a part of the world where both production and refining are expanding rapidly. At Haifa, on the eastern shore of the Mediterranean, a new refinery to process 30,000 bbl. daily of Iraq crude is now approaching completion. On Bahrein Island in the Persian Gulf the recently erected plant of Bahrein Petroleum Co. has been twice enlarged since construction started. It now has a daily capacity of 35,000 bbl. and will have to undergo further expansion to handle the increasing output of crude unless the owners decide to build other refineries. At Abadan in southern Iran one of the world's largest and most complete refineries is in process of constant growth and plans have been drawn for a second large plant to handle the output of new fields now under development.

Local demand in this great area is very limited and is supplied by various small plants. While the products of the Bahrein refinery find their markets east of Suez and part of Abadan's production also supplies that area, some portion of the output of all

Night view of the central chemical station of the ANCAP refinery in Montivideo, Uruguay.





ANCAP cracking unit which ran for over 114 days on 27 deg. A. P. I. topped crude.

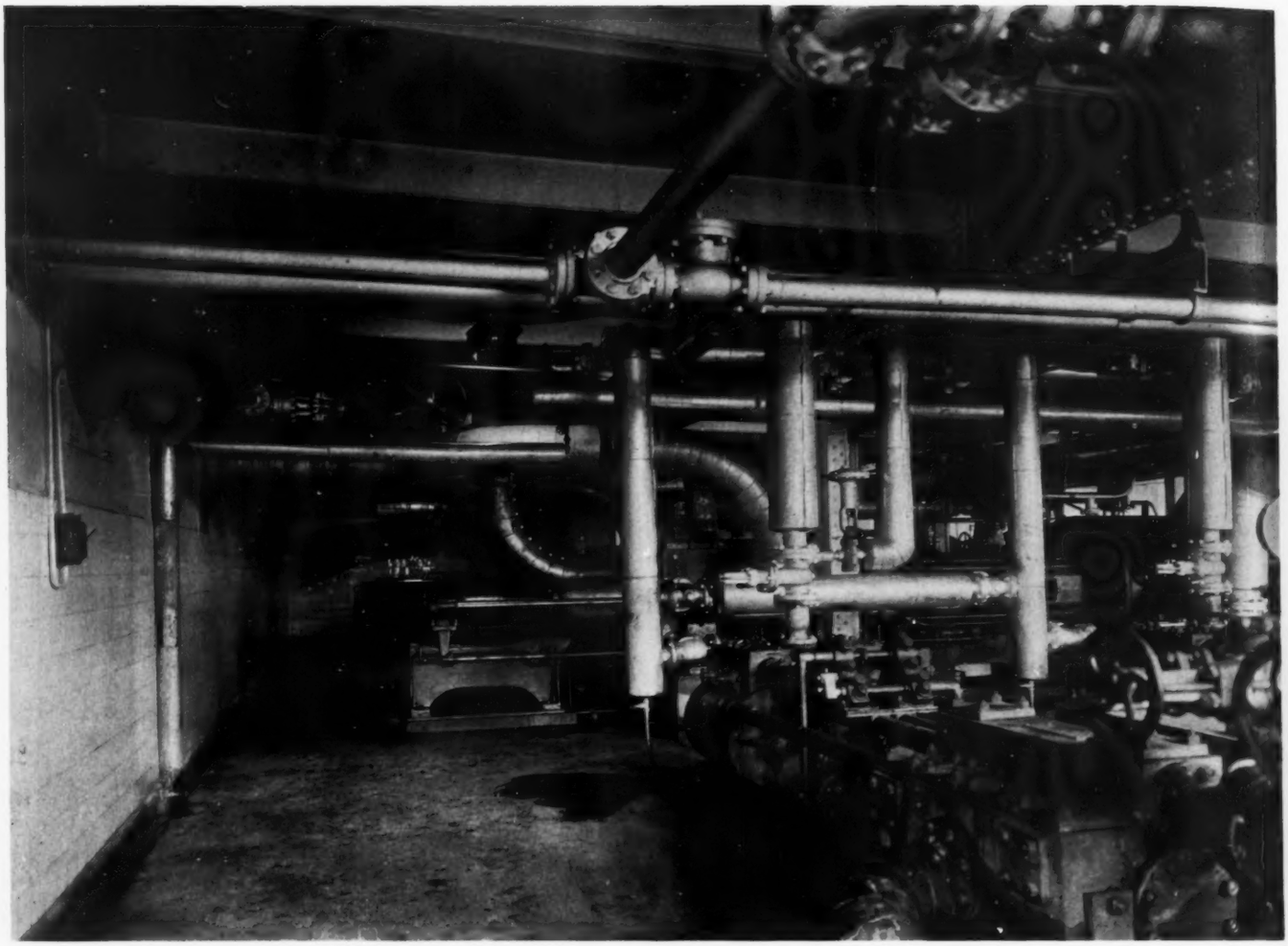
three of these large plants will be available to meet the war requirements of Britain and France if needed for that purpose.

Another developing center of production and refining is in the East Indies. Against a yearly production of 55,000,000 bbl. there exists refining capacity for about half that amount. While there is a market for these refined products in the East they too can be made available in part to Western Europe in the absence of more conveniently located supplies.

In the Western Hemisphere the situation in the United States already has been referred to and it has been shown that ample refining capacity exists to supply up to 25,000,000 tons or more annually without interfering with the country's domestic trade. Outside the United States the only country in the northern continent that is able to provide petroleum products for export is Mexico. A large amount of crude has been moving from Mexico to Germany during the past year but direct trade between the two countries has been cut off by the war blockade. Mexican oil has been barred from the United Kingdom because of Mexico's confiscation of oil properties belonging to British subjects. Under stress of war this position might be changed.

Next to the United States the most dependable source of gasoline and fuel oil for Britain and France is the Netherlands West Indies. Here, on the islands of Aruba and

Company	*Plant Location*	*Daily Capacity (Bbl. crude)*
Germany—Continued		
Rhenania-Ossag Mineraloelwerke	Monheim	2,000
	Hamburg-Grasbrook	2,500
	Harburg-Wilmsburg	5,000
	Freital nr. Dresden	200
	Harburg-Wilmsburg	2,000
	Reisholz B. Dusseldorf	1,400
	Regensburg	350
Schindler, Julius, Oelwerke G. m. b. H.	Neuhof, nr. Harburg-Wilhelmsburg	700
	Peine, Hannover	350
Schliemann's Ernst. Oelwerke	Hamburg-Grasbrook	1,500
	Harburg-Wilhelmsburg	1,500
Shell-Floridsdorfer Mineraloel Fabrik, A. G.	Vienna Floridsdorf	3,800
Vacuum Oil Co., A. G.	Kagran	
Westfalische Mineraloel-und Asphaltwerke W. H. Schmitz Kommandit Gesellschaft	Dortmund-Sud	300
Zeller & Gmelin	Eislingen	250
Bohemia-Moravia		
Fanto Werke A. G.	Bohemia	1,100
	Pardubice	4,000
Kraluper Mineraloel-Raffinerie Lederer & Co.	Kralupy	1,000
"Petrolen" Oil und Fett Werke A. G.	Prague	1,000
Perivozer Mineraloelwerke A. G.		1,300
Vacuum Oil Co. S. A.	Kolin	2,100
Slovakia		
Apollo Mineraloel Raffinerie A. G.	Bratislava	1,600
	Weikersdorf	400
Sudkarpatische Mineraloel-Raffinerie und Handels A. G.	Makacsoo	1,200
"Vesta" Slovakische Mineraloel-industrie A. G.	Bratislava	200
Hungary		
Fanto Vereinigte Ungarische Mineraloelfabriken A. G.	Budapest	1,000
	Satorjala Ujhelij	280

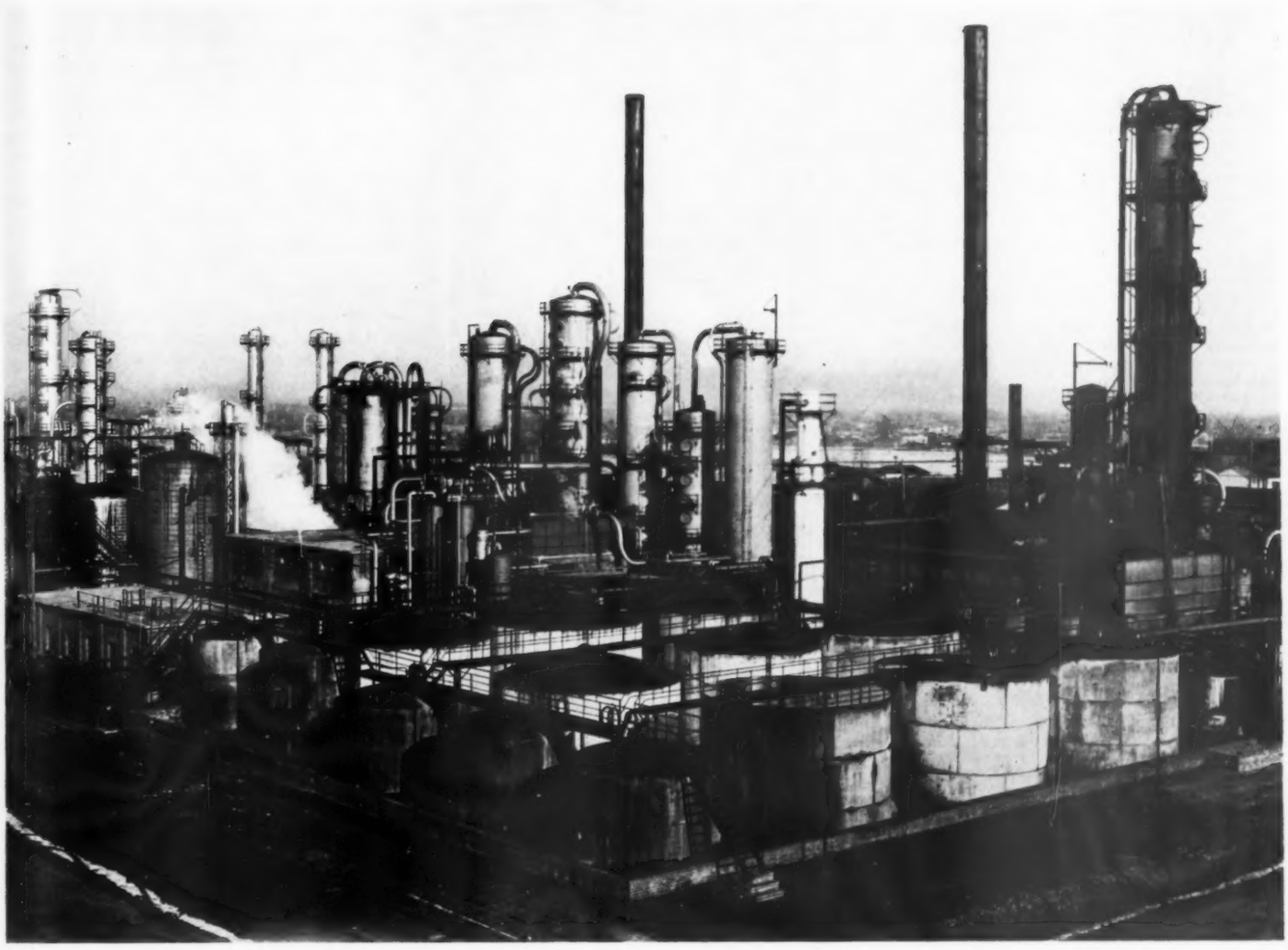


Interior and exterior views of the Colombia refinery in Roumania which occupies a key position in warring Europe.

Company	*Plant Location*	*Daily Capacity (Bbl. crude)*
Hungary—Continued		
Hazai Koolajipar R. T.	Budapest	1,170
Hungarian Hydrobenzine Co. (Magyon Hydrobenzion Reszvenytarsasag)	Petfurdo	
Nyirbogdanyer Petroleumfabrik A. G.	Nyirbogdany	280
Shell Mineraloel A. G.	Budapest-Csepel Harbor	2,300
Szoreger Petroleumfabrik A. G.	Szoreg	420
Ungarische Petroleum-Industrie A. G. (Magyar Petroleum-Ipar Reszvenytarsasag)	Budapest	2,000
Vacuum Oil Company	Almas Fuzito	——
Irish Free State (Eire)		
Cork Harbour Oil Wharves, Ltd.	Haulbowline Island	600
Munster, Sims & Co. (Dublin) Ltd.	Dublin	1,000
Italy		
Aquila (Redeventza)	Trieste	6,000
Azienda Generale Italiana Petroli (A. G. I. P.)	Porto Marghere (Venice)	14,000
Azienda Nazionale Idrogenazione Combustibili	Bari	4,400
	Ligorni	4,400
"Nafta" Societa Italiana Pel Petrolio Ed Affini (Shell)	La Spezia (Migliarina)	12,000
Petroli D'Italia Societa Anonima	Fiorenzuola D'Arda Piacenza	200
Raffineria Di Napoli, S. A. I.	Naples	5,000
Raffineria Di Olii Minerali Societa Anonima (Romsa)	Fiume	2,500
Societa Italo Americana Pel Petrolio	Trieste	2,000
Societa Petrolifera Italiana	Fornovo Taro (Parma)	1,000
Latvia		
Oehlrich A. & Co.	Muehlgraben	150

Curacao, are three refineries capable of processing 26,000,000 tons of oil yearly all of which is exported. Petroleum products from the Netherlands West Indies have been regularly shipped to Europe in the past and these islands have been one of the main sources of import supply for Germany. With trade to Germany shut off the shipments formerly going to that country may find their way to England and France.

While the continuance of hostilities in Western Europe is certain to bring about a greatly increased demand for certain petroleum products, a review of existing refining facilities shows that Europe itself is not in a position to supply these and that in fact the most reliable sources from which the warring countries, at least Britain and France, can obtain them are the United States and the Netherlands West Indies. In these two places is to be found the combination of ample production in close juxtaposition with a large refining capacity capable of rapid expansion in case of necessity. The distance to be covered in transport is much less from the West Indies or the Atlantic coast of the United States to western Europe than it is from either the Near or Far East while the difficulty of guarding cargoes from attack en route is less. For all these reasons it is probable that



the refineries of the Western Hemisphere will be the main reliance of Britain and France for the additional supply of those products most needed for the carrying on of modern war.

One immediate effect of the war has been to set in motion a widespread series of activities directed toward increasing the capacity for producing gasoline, fuel and lubricating oil to meet the heavy demands of armies and navies in action. In the refining departments of international oil companies, in engineering offices and in the drafting rooms of construction firms work is being pushed in complete disregard of normal working hours to plan and equip new units and added capacity for those plants most favorably located to supply military and naval needs. As a matter of precaution against attempts at sabotage information is being withheld regarding these undertakings. Consequently it is impossible to describe or even to refer to some of the most interesting and important work in refinery construction and expansion that is under way at the present time. It is revealing no secret, however, to say that in all the countries involved in the conflict the refining industry is being put on a war footing and every effort is being made to conserve the use and increase the

Company	*Plant Location*	*Daily Capacity (Bbl. crude)*
Netherlands		
N. V. De Bataafsche Petroleum Maatschappij	Rotterdam	5,700
Norway		
Akt. Norsk Amerikansk Mineral-Oljecompagnie	Vallo, nr. Tonsberg	1,000
Vallo Oljeraffineri A. S.	Vallo, nr. Tonsberg	1,200
Poland		
Bacher I, Spolka, Dr. Rafinerja Olejow Mineralynch	Derezyce	100
Bolechow Zwiazkowa Rafinerja Nafty I Zaklady Przemyslowe Spolka, Z. O. O.	Dolzka	100
Chaskiel Gliecher I Syn.	Ropica Polska	100
Derezycka Rafinerja Olejow Mineralnych I Fabryka Produktow Chemicanych Spolka Z. O. O.	Derezyce	125
Ehrenberg, Samuel & Hollender	Gorlice	100
Fabryka Wytworrow Chemicanych Spolka, Z. O. O.	Drohobycz	100
"Fanto" (Spolka Akcyjna "Fanto")	Ustryzki Dolne	1,000
Friedmann, J. S.	Kolomyja	100
Galicyjskie Towarzystwo Naftowe "Galicja" Spolka Akcyjna (Galizische Naphtha-Aktien-Gesellschaft "Galicia")	Drohobycz	3,000
"Gazy" Ziemne Spolka Akcyjna Dla Przemyslu Naftowego UL.	Zniesienie, suburb of Lwow	500
Haber Freres G. m. b. H. Petroleum-Raffinerie	Stanislawow	150
Hubicka Rafinerja Olejow Mineralnych Sp. Z. O. O.	Hubicze, nr. Drohobycz	100
Jaslo, Industrial Oil Works, Gartenberg & Schreyer	Nieglowice and Jaslo	1,100
Limanowa (Towarzystwo Naftowe Limanowa Spolka Z. Ogr. Odp.)	Limanowa, East Galicia	2,000
Malopolska Grupa Francuskich Towarzystwo Naftowych	Warsaw Lwow Drohobycz Trzcebinia Glinik Mariampolski Jedlicze Boryslaw	

Company	*Plant Location*	*Daily Capacity (Bbl. crude)*
Poland—Continued		
Malopolski Przemysl Olejow Mineralnych Sp. Z. O. O.	Klecgany	100
Malopolskie Towarzystwo Dla Przemyslu Naftowego Kleczany Spolka Z. O. O.	Klecgany	100
"NAFTA" Spolkaz Akcyjna	Drohobycz	100
"Naftamin" Spolka Akcyjna Dla Przemyslu Naftowego	Ligota Pszczynska	300
Polmin State Oil Works in Drohobycz (Polmin Panstwowa Fabryka Olejow Mineralnych	Drohobycz	3,500
Polska Nafta S. A.	Kolomyja	100
Polskie Zwiazkowe Refinerje Olejow Skalnych Spolka Akcyjna (Polish United Oil Refineries)	Rychoice, nr. Drohobycz	700
	Trzebionka, nr. Chrzanow	1,400
Refinerja Nafty "Gleboka" Spolka Z. O. O.	Gleboka by Sambor	100
Rafinerja Nafty I Fabryka Olejow Maszynowych, M. H. Reich I. Ska.	Stryj.	250
Rafinerja Nafty I Olejow Mineralnych Adolf Krua	Krechowicach	100
Rafinerja Nafty "Iwonicz" Spolka Z. O. O.	Targowiska	100
Rafinerja Olejow Mineralnych Inz. Dr. Baltuch, Lieberman I. Marmelstein	Boryslaw	100
Rafinerja Olejow Mineralnych "Selgli" Spolka Z. O. O.	Nadworna	200
Rafinerja Skawinska Zaklady Dla Przemyslu Oleju Skalnego Griffel I Ska	Skawina	300
Rafinerja "Wierbiarz" at Kolomyja Fabryka Przetworow Olejow Skalnych	Wierbiarz	100
Societe Francaise Industrielle et Commerciale Des Petroles	Jedlicze, Poland	1,500
	Glinik Marjampolski, nr. Gorlice	1,200
Standard Nobel Co. in Poland, Ltd. (Standard Nobel W Polsce, Spolka Akcyjna)	Libusza, nr. Gorlice	1,100
Stawiarski R. W. & Co. (Fabryka Nafty "Walerjan Stawiarski I Ska." Sp. Z. O. O.)	Krosno	600
Vacuum Oil Co., S. A.	Czechowice	2,500
Zachariasz Handel	Drohobycz	100
Roumania		
"Astra Romana" Societate Anonima	Ploesti-Sud	40,000
"Astra" Romana-Xenia Societe Anonima	Ploesti-Nord	6,000
Berman, J.	Bucovat-Chisinau	180
Blum, B. & Z. Fainaru	Margineni-Bacau	220
"Carmen Petrol" Societate Anonima Romana Pentru Mine Si Petrol	Targoviste	2,250
"Colombia" Societe Franco-Roumaine De Petrole	Ploesti-Sud	6,000
"Cometa" S. A. R. Pentru Industria Si Comertul Petrolului	Ploesti-Nord	3,000
"Concordia" Vega Societe Anonyme Roumaine Pour L'Industria Du Petrole	Ploesti-Nord	31,000
Creditul Minier S. A. R. Pentru Desvoltarea Industrei Miniere	Aurora-Baicoi	6,600
	Brazil-Prahova	8,400
	Doicesti-Dambovitza	1,800
Dacio Romano Petroleum Syndicate, Ltd., Lon	Ploesti	4,000
	Ploesti	3,500
Dumbrava	Targoviste	330
Fratia	Ploesti-Sud	3,200
Freund Fratii	Satu Mare	133
Friedman, J.	Dej.	800
Grigorescu, J.	Prisaca-Targoviste	1,600
Helios Soc. Anonima Fabrica De Petrol	Colanu, nr. Targoviste	100
Industrille De Petrol Orsovileagd S. A.	Orsova	1,000
"Moldonaphtha" Societate Anonima Romane Pentru Industria Si Comertul Petrolului	Lucacesti (Moinesti)	600
Niculescu, Ciufu J.	Ulmi-Targoviste	650
Noris	Ploesti-Sud	1,300
"Petrol Block" Societate Anonima Romana	Ploesti (Standard)	15,000
	Buzau (Saturn)	500
	Bucarest (Bancasa)	2,000
	Plopeni	500
"Petrolmana" Societate Romana Di Mine Si Petrol	Ploesti-Sud	3,300
Petrolul Bucuresti	Bucarest-Crivita	4,650
Petrolul Bucovinean	Rohozna-Cernauti	450
Petrol Latina	Plopeni-Prahova	1,200
"Photogen" Rafinerie De Petrol S. A.	Brasov	1,350
"Prahova" Societate Anonima Romana Pentru Industria Si Comertul Petrolului	Bucarest	7,000
Progresul	Tatarani-Prahova	330
"Rafinaria De Petrol Din Targul Mires"	Targul-Mures	200
Rafinajul, Societe Anonyme Roumaine De Petrole	Lumnia	7,000
Rafinaria De Petrol "Titan" S. A. R.	Bucarest	400
"Rafinariile Predinger" Societate Anonima	Ploesti	——
"Redeventa" Societate Anonima Pentru Exploatarea SI Comertul Produselor Subsolului	Ploesti-Nord	5,200
Revoil	Baicoi-Prahova	160
Romana-Africana, S. A. R.	Ploesti	4,800
Romano-Americana S. A. Pour L'Industrie, Le Commerce Et L'Exportation Du Petrole	Teleajen, nr. Ploesti	30,000
Romano-Belgiana De Petrol" Societate	Ramnicul-Sarat	1,000
Roumanian Consolidated Oilfields, Ltd.	Targoviste	2,000
Schwartz, A.	Onesti-Bacau	180
Smarack, Dr. D.	Roznov-Meamt.	330
Soc. Generala Mine & Petrol	Doicesti-Dambovita	2,700
Steinberg, H. I.	Brasov	400
Spies Petroleum Co., Ltd.	Ploesti "Xenia"	4,800
Steaua "Romana" S. A. Pour L'Industrie Du Petrole	Campina	34,000
	Moinesti	1,780

output of those products most in demand for military operations. At the same time in other countries, wherever the locations of refineries are such as to make their output available to the contending nations, special units are being installed and additional capacity is being provided to increase the provision of those products most in demand. Developments inspired by the war will make the coming year one of record activity in this branch of the petroleum industry.

Entirely aside from the developments directly inspired by the war which naturally will not assume concrete form until after the turn of the year the refining industry is characterized by constant progress both in methods and equipment. Such progress has been strikingly in evidence during 1939. Perhaps the outstanding feature of the current year has been the extent to which new construction has turned to the installation of new processes for turning out products of a specialized character and for imparting greater flexibility to refining operations.

In the United States the outstanding development in this line has been the number and size of installations of Houdry units for catalytic cracking and treating. Although formal announcement of the Houdry processes was made only a year ago a dozen American installations and three in Europe are now in operation or in process of construction at a cost of some $35,000,000. The daily charging capacity of these plants is over 200,000 bbl. and the cracking capacity is over 160,000 bbl. Among the largest of the installations are the cracking and treating units at the Marcus Hook and Toledo refineries of Sun Oil Company, at the Beaumont refinery of Magnolia Petroleum Company and at the Augusta, Kan., Paulsboro, N. J. and East St. Louis, Ill., plants of Socony-Vacuum Oil Company. A full description of the Houdry process and Houdry installations appears in another part of this issue.

Applications of catalysis to the production of high test products might in fact be described as providing the keynote of the year's activities. The catalytic cracking process of Universal Oil Products Company is being installed in a number of refineries while other catalytic reforming and treating systems have been worked out and are being put into operation.

Another noteworthy development of the year has been the widespread adoption of alkylation as a means of increasing the production of high-octane aviation gasoline. Through the combination of patents and processes developed by Anglo-Iranian Oil Company, Shell Development Company, Standard Oil Company (New Jersey) and Texaco Development Corporation this system has been made available to oil companies generally and a dozen or more plants have been completed or are now under construction. The special recommendation for alkylation is the facility with which high test aviation fuel can be produced at moderate cost and with a relatively small investment.

While a large part of the expansion of American refining facilities has taken the

form of additions of new processing units to existing plants, the development of new capacity along conventional lines has been marked by its usual growth. On the Pacific Coast the most important single addition to the number of refining establishments was the completion and opening of the large plant of Richfield Oil Company at Watson, Calif. This refinery which was fully described in an earlier issue* handles 50,000 bbl. of crude daily and includes two combination topping and cracking units, polymerication and stabilization equipment. More recently a Stratcold acid treating unit has been added to its equipment. This is described in this issue.

At Santa Fe Springs, California, Eagle Oil & Refining Co. has installed a Dubbs cracking unit of 3,000 bbl. daily capacity and an Ethyl blending unit. Fletcher Oil Co., near Wilmington, has added Dubbs cracking and U. O. P. polymerization units for the treatment of gas oil, fuel oil and gas. Among improvements which Union Oil Co. has under way at a cost of $2,000,000 are an alkylation plant and a vacuum distillation unit.

In the Rocky Mountain region several additions to refining capacity have been made in Montana. Glacier Petroleum Co., at Cut Bank, has installed a combination skimming, cracking and polymerization plant. The cracking equipment consists of a 2-coil Dubbs unit of 2,100 bbl. daily capacity and the U. O. P. polymerization unit is designed to process 460,000 cu. ft. of gas daily. At Great Falls, the Home Oil & Refining Co. has installed a U. O. P. catalytic polymerization unit and at Chinook the North American Refining Co. has constructed a 500-bbl. plant. At Alamosa, Colo., a Dubbs cracking unit of 1,000 bbl. capacity has been erected by the Hughes estate.

Large combination units have been installed by Humble Oil & Refining Co. at Baytown, Texas, by Continental Oil Co. at Ponca City, Okla. and by Shell Oil Company at Houston. In addition to its two large Houdry units Magnolia Oil Co. has added an alkylation plant to its refinery at Beaumont, Texas.

Taylor Refining Co. has constructed at Corpus Christi, Texas, a 10,000-bbl. crude unit, a 5,000-bbl. naphtha rerun unit and a 3,000-bbl. stabilization system. At the same place Barnsdall Refining Co. increased the capacity of its refinery to 20,000 bbl. daily. Cosden Refining Co. erected at Graham, Texas, a 2,500-bbl. skimming plant and an absorption plant to process 5,000,000 cu. ft. of gas daily. Mankins' Refining Co., Wichita Falls, built a 1,500-bbl. skimming plant in the KMA, Texas, field. Ben Franklin Refining Co., subsidiary of Bell Oil & Gas Co., installed a Dubbs cracking unit, a polymerization unit, an absorption and stabilizing plant, a gum inhibiting system and a copper sweetening unit at Ardmore, Okla. Mid-Continent Petroleum Co., at Tulsa, added a lubricating oil unit to its refinery. At Phillipsburg, Kansas, a refinery is being erected equipped with a 1,500 bbl. Dubbs Cracking Unit.

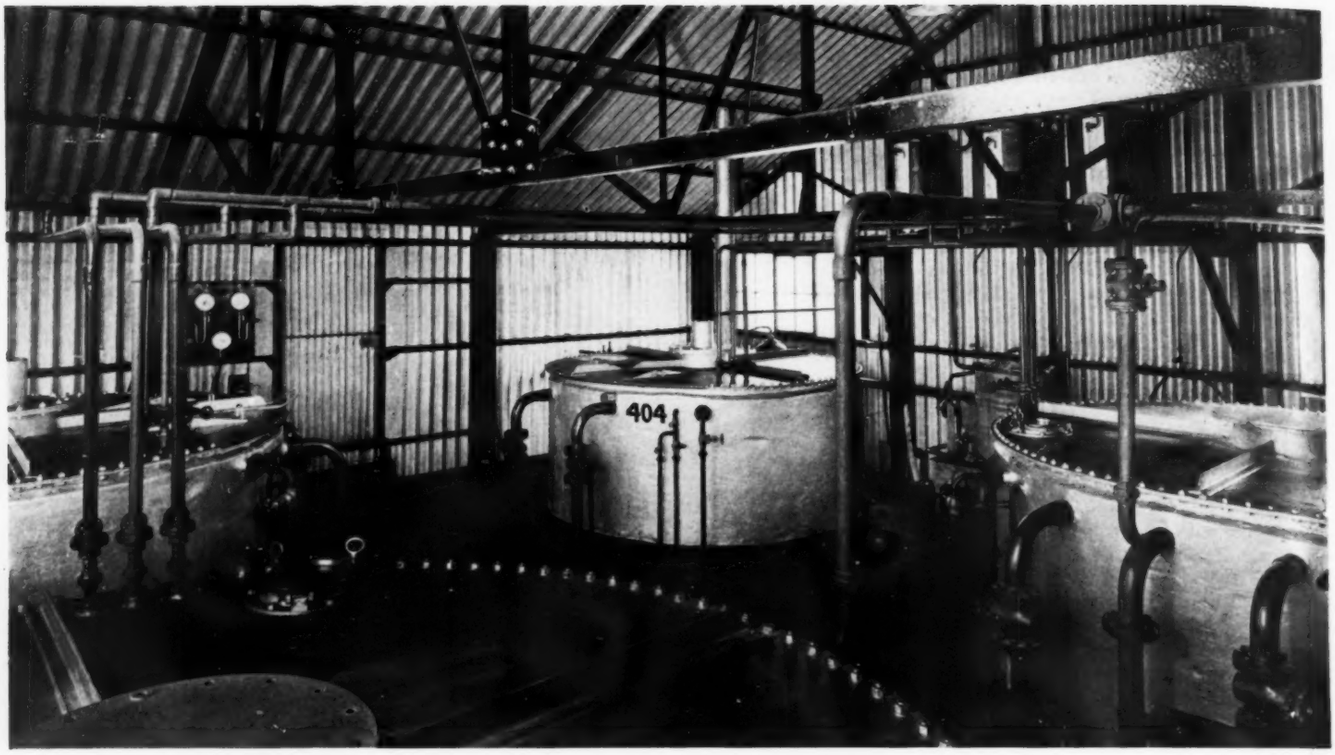
At Shreveport, La., Arkansas Fuel Oil Co. has installed a thermal polymerization unit, a

* World Petroleum, March, 1939

Company	*Plant Location*	*Daily Capacity (Bbl. crude)*
Roumania—Continued		
Titan	Bucarest-Cioplea	1,070
"Unirea" Societate Anonima Romana De Petrol	Ploesti (2)	25,500
Venus, R.	Sarat	1,460
Spain		
Compania Arrendataria Del Monopolio De Petroles S. A.(Campsa)	Cornella (Barcelona)	700
Compania Espanola De Petroleo S. A. (Cepsa)	Santa Cruz de Teneriffe, Canary Islands	5,000
Sweden		
Johnson & Co., A.	Nynashamm	1,200
Nyneas-Pet. A. B.	Nynaeshamm, nr. Sako	7,000
United Kingdom		
Agwi Petroleum Corp., Ltd.	Fawley, nr. Southampton	12,000
Anglo-American Oil Co., Ltd.	Ellesmere Port	480
Berry, Wiggins & Co., Ltd.	Kingsnorth, nr. Rochester, Kent (2)	2,300
	Weaste (near Manchester)	1,500
	Stanlow Sidings, Ellsmere Port, Wirral, Cheshire	
Briggs & Son, Ltd.	Dundee	1,050
Cory Brothers & Co., Ltd.	Coryton (nr. London)	6,000
Doncaster Coalite, Ltd.	Askem, nr. Doncaster, Yorks	3,500
Green Herbert & Co., Ltd.	East Halton, Habrough, Lincolnshire	1,500
I. C. I. Ltd. (Coal Hydrogenation)	Billingham-on-Tees	2,800
Keys, W. H., Ltd.	Avonmouth	500
	West Bromwich	500
Lobitos Oil Fields, Ltd.	Ellesmere Port	2,500
London & Coastal Oil Wharves, Ltd.	Canvey Island, Thames Estuary	
London & Thames Haven Oil Wharves, Ltd.	Thames Haven (nr. London)	
Low Temperature Carbonisation, Ltd.	Barugh, nr. Barnsley, Yorks	1,750
Major & Co., Ltd.	Hull	1,500
Manchester Oil Refinery, Ltd.	Barton, Manchester	2,000
National Oil Refineries, Ltd.	Llandarcy, South Wales	20,000
Pumpherston Oil Co., Ltd. (Shale Oil)	Pumpherston	3,000
Redline-Glico, Ltd.	Pacific Wharf, West Ham, London	
Scottish Oils, Ltd. (Shale)	Grangemouth, Scotland	7,000
Shell Refineries, Ltd.	Ardossan (nr. Glasgow, Ayrshire)	5,000
	Shell Haven (nr. London)	16,000
	Stanlow, Ellesmere Port, Manchester Ship Canal	15,000
U. S. S. R.		
Glavneft (Petroleum Div. of the Commissariat for Heavy Industries)		
Aviatop	Moscow	97,500
	Gorki, Yaroslavi	20,400
	Saratoff (8 units)	32,000
	Leningrad	4,750
	Odessa	5,800
	Kherson	4,000
	Berdiansk	4,000
Emba	Varinsk	5,700
	Konstantinovka	12,500
	Orsk	17,500
Grozni	Grozni	
	Tuapse	
	Makhatch Kala (Total all plants)	373,000
Maineft	Krasnodar	22,000
Middleasia	Melnikovo	
Vostokneft	Santo and Chimion	3,500
Sakhalinneft	Khabarovsk	3,000
	Vladivostok	
Yugoslavia		
Anglo-Yugoslave Petroleum Co.	Caprag on Kupa River	1,500
Dravogradska Rafinerija Mineralnega Olja G. Goll Sen., D. Z. O. Z.	Dravograd	150
"Ipoil" Dr. Ivanovic & Co.	Osijek	5,000
Shell Company of Jugoslavia, Ltd. (Jugoslavensko Shell D. D.)	Caprag	1,900
Standard-Vacuum Oil Co. of Jugoslavia, Inc.	Bosanski Brod	2,000

AFRICA

Egypt		
Anglo-Egyptian Oilfields, Ltd.	Suez	7,000
Raffinerie de Petrole du Government	Suez	500
Union of South Africa		
South African Torbanite Mining & Refining Co., Ltd.	Durban	1,000



Interior view of the new Manchester refinery in England.

Company	*Plant Location*	*Daily Capacity (Bbl. crude)*
	ASIA	
Bahrein Island		
Bahrein Petroleum Co., Ltd.	Manama, Bahrein, Persian Gulf	35,000
Burma		
British Burmah Petroleum Co., Ltd.	Thilawa on Rangoon River	2,500
Burmah Oil Co., Ltd.	Syriam, on Peju River	25,000
Indo-Burmah Petroleum Co.	Seikgyi, on Rangoon River	3,500
	Kindat, on Chindwin River	300
India		
Assam Oil Co., Ltd.	Digboi, India	7,000
Attock Oil Co., Ltd.	Rawalpindi, Punjab	2,000
Nathsingh Oil Co., Ltd.	Yenangyaung, Upper Burma	200
Iran		
Anglo-Iranian Oil Co., Ltd.	Abadan	280,000
	Kermanshah	25,000
	Masjidi-Sulaiman	
Iraq		
Iraq Petroleum Co., Ltd.	Baba Gurgur	150
Khanaqin Oil Co., Ltd.	Khanaqin	7,000
Japan		
Aikoku Oil Co.	Kawaski, Kanagawa	——
Aoki Oil Co.	Nishi Uwa Gun Ehime	——
Asahi Oil Refinery Co.	Joto-Ku	250
	Shimonosiki	250
Chosen Oil Co.	Genzan, Korea	——
Edogawa Oil Co.	Edogawa-ku, Tokyo	——
Eizo Saito	Sekiya, Niigata	——
Fuji Oil Mfg. & Transportation Co.	Sasebo, Nagasaki	——
Fukutaro Takeda	Nishi Uwa Gun, Ehime	——
Hayama Oil Co.	Funkawa, Akita	——
	Sekiya, Niigata	——
	Kawasaki, Kanagawa	——
Hirasawa Refinery, Ltd.	Yuri-Gun, Akita	——
Irini Co., Ltd.	Mishima-Gun, Niigata	——
Ishizaki Refinery, Ltd.	Niitsu, Niigata	——
Japan Mining Co.	Minami Akita-Gun, Akita	——
Japan Motor Oil Co.	Ube, Yamaguchi	——

gas oil cracking unit, a naphtha reforming plant. The cracking and reforming capacity is 2,000 bbl. daily. At El Dorado, Ark., Lion Oil Refining Co. has added a Lummus cracking and reforming unit, and Root Petroleum Co. has installed a U. O. P. polymerization plant to process 1,050,000,000 cu. ft. of gas daily.

The most important program of extension being carried out in the central states is that of Shell Oil Co. at its Wood River, Ill., refinery. These changes will increase the capacity of the plant from 50,000 to 75,000 bbl. daily. They include a 25,000-bbl. crude topping plant, an 18,000-bbl. Dubbs unit for cracking heavy oils, an alkylation plant and extensions of the chemical, coking and lubricating oil plants. With improvements in auxiliary equipment the entire program will call for the expenditure of $8,000,000 or more.

Rapid expansion of production from the Illinois fields has led to the establishment of a number of refineries in that area. Among these are the 2,000-bbl. skimming plant of Central Illinois Refining Co. at Centralia, the skimming and Dubbs cracking plant of Pana Refining Co. at Pana with a capacity of 4,000 bbl., a skimming and cracking plant of Taxman Refining Co. at Centralia, 2,000-bbl. plants of Lake Refining Co., near Salem and Cascade Refining Co. at Selmaville, and a 3,000-bbl. skimming and cracking plant of Cumberland Production Co. at Salem. A number of other plants of similar size are projected for this area.

At Whiting, Ind., the Standard Oil Co. of Indiana has added a combination unit of 22,000 bbl. capacity and a large iso-octane

installation for the production of aviation fuel. At Alma, Mich., a Dubbs cracking unit of 1,000 bbl. daily capacity and a reforming unit handling 200 bbl. daily have been installed by Midwest Refineries.

In the eastern states important installations have included Houdry units at the Toledo, Ohio, and Marcus Hook, Pa., refineries of Sun Oil Company and at the Paulsboro, N. J., Brooklyn, N. Y., Buffalo, N. Y., and Detroit, Mich., plants of Socony-Vacuum Oil Co. Atlantic Refining Co. installed a 20,000 bbl. distillation unit at its Philadelphia refinery. Sinclair Refining Co. added a Texaco solvent dewaxing unit to its refinery at Wellsville, N. Y., and a Universal Oil Products catalytic polymerization unit was installed by a group of independent Pennsylvania companies.

The above is not intended as a complete record of all changes and additions to refining plants during the past years (such a record would occupy more space than is available here) but as representative of the trends observable in refinery construction and equipment. On the one hand there is shown a tendency to broaden the scope and enlarge the capacity of large plants in order to produce a full range of products and to effect economies by the utilization of former wastes. On the other hand refineries of small capacity continue to multiply and find a satisfactory field in serving the needs of local territories. Many of them are strengthening their economic position by introducing cracking and polymerization units and find no difficulty in maintaining a competitive position. There is nothing in the developments of the past year to support the prediction sometimes heard that small refineries will be forced out of existence.

As Canada's Turner Valley field continues to expand in production, enlarged refining capacity is called for in the western provinces of the Dominion. In May last a new 5,000-bbl. plant of British-American Oil Co. was put into operation at East Calgary, Saskatchewan. Imperial Oil Ltd. has enlarged the capacity of its Calgary refinery to 7,000 bbl. daily and is engaged in making additions to its plant at Regina, Saskatchewan, to 7,500 bbl. daily. Anglo-Canadian Oils, Ltd., has installed a Dubbs cracking unit at Brandon, Manitoba, and several skimming plants of small capacity have been built in the Turner Valley area. The latest undertaking in this field is that of Consumers Cooperative Refineries Ltd. which has completed arrangements for a refinery of 1,500 bbl. daily capacity with Dubbs cracking equipment at Regina.

In the Netherlands West Indies continued additions to the huge plants of Lago Oil & Transport Co. on Aruba and Curacaosche Petroleum Ind. Mij at Curacao make these small islands one of the world's most important refining centres, the daily capacity of the two being upward of 500,000 bbl. A wide range of light and heavy products is turned out by these plants.

While the refineries of the Netherlands West Indies operate mainly on Venezuelan

Company	*Plant Location*	*Daily Capacity (Bbl. crude)*
Japan—Continued		
Japan Oil Mining Co.	Yabari-Gun, Hokkaido	——
	Mishima-Gun, Niigata	——
	Nishi-Kubiki-Gun, Niigata	——
Jisaburo Shimidzu	Nakakubiki-Gun, Niigata	——
Kato, Ltd.	Nagaoka, Niigata	——
Kiichi Wada	Sekiya, Niigata	——
Kikuzo Komi	Nakakubiki, Niigata	——
Kintaro Nagai	Minami-Akita-Gun, Akita	——
Kitamura Oil Co.	Choshi, Chiba	——
Kobayashi Co., Ltd.	Nagaoka, Niigata	——
Kokura Oil Co.	Kariha-Gun, Niigata	——
	Joto-Ku, Tokyo	——
	Kanagawa-ku, Kanagawa	——
Kyushu Refinery, Ltd.	Tobata, Fukuoka	——
Manchukuo-Japan Petroleum Co.	Kanchingtsu, Manchukuo	——
Manchurian Railways (Shale Oil)	Fuchun (Manchuria)	700
Maruzen Machine Oil Co.	Osaka and Niitsu, Niigata	680
Masakichi Hara	Numadare, Niigata	——
Matsuyo Kaneko	Yamanto-Gun, Akita	——
Mikado Oil Co.,	Akashi-Gun, Hyogo	——
Mitsubishi Oil Co., Ltd.	Ogimachi, Kawasaki City, Kanawage	5,000
Nanaki Oil Co.	Kainan, Wakayama	——
Nippon Oil Co., Ltd. (Nippon Sekiyu Kabushiki Kwaisha)	Kashiwazaki	2,800
	Niigata	2,800
	Akita	3,000
	Tsurumi	3,500
	Kudamatsu	3,500
	Hokkaido	300
	Byoritsu	200
Ogura Oil Co., Ltd. (Ogura Sekiyu Kabushiki Kaisha)	Oshima, Tokyo	3,500
	Ysurumi, Yokohama	1,500
	Yzurumi, Yokohama	3,500
Osaka Mineral Oil Refinery, Ltd.	Osaka City, Osaka	——
Seiicho Kato	Nagaoka, Niigata	——
Seiji Okura	Niitsu, Niigata	——
Shinsuke Fuse	Haruhara-Gori, Shidzuoka	——
Takahashi Oils & Fats Co.	Moji, Fukuoka	——
Takejo Morobashi	Minami Akita-Gun, Akita (2)	——
Tasaburo Tamiya	Tsurumin, Jabagawa	——
Tatsuji Ohya	Niitsu, Niigata	——
Toho Oil Co.	Tsurumi, Kanagawa	——
Tomitaro Matsuoka	Matsuyama, Enime	——
Toraichiro Terai	Nagaoka, Niigata	——
Toshiji Matsubashi	Nakakubiki, Niigata	——
Toyo Petroleum K. K.	Osaka	340
Toyo Shoko Oil Co.	Osaka City, Osaka	
	Tsurumi, Kanagawa	——
Tsunegoro Asada	Sekiya, Niigata	——
Tsunekichi Niitsu	Yuri-Gun, Akita	——
	Yamanoshita, Niigata (2)	——
	Kariha-Gun, Niigata	——
Tsunekichi Ohya	Mishima-Gun, Niigata	——
Tsurumatsu Matsumura	Mishima-Gun, Niigata	——
Ukichi Suziki	Nagaoka, Niigata	——
Ushida Oil Co.	Nishi-Harui-Gun, Ajchi	——
Washio Refinery, Ltd.	Nagaoka, Niigata	——
Yamagishi Co., Ltd.	Numadare, Niigata	——
Netherlands India		
Algemeene Petroleum Compagnie	Klantoeng, Java	100
N. V. De Bataafsche Petroleum Maatschappij	Balikpapan, East Borneo	35,000
	Pangkalan Brandan, Sumatra	12,000
	Pladjoe, Sumatra	18,000
	Soeban Djerigi, Sumatra and Boela Bay Ceram	——
	Theope, Java	14,000
	Wonokromo	2,000
Nederlandsche Koloniale Petroleum Maatschappij	Kapocan, Java	500
	Soengei Gerong, Sumatra	43,000
Siam		
Siamese Navy, Fuel Dept.	Bankok	500

AUSTRALASIA

Australia		
Commonwealth Oil Refineries, Ltd.	Kororoit Creek, nr. Williamstown Laverton, Victoria	2,000
Newport Oil Refinery, Ltd.	Newport	——
Shell Co. of Australia, Ltd.	Clyde	2,000
New Zealand		
New Zealand Oil Refineries, Ltd.	New Plymouth	——

Company	*Plant Location*	*Daily Capacity (Bbl. crude)*

NORTH AMERICA

Canada

Alberta Hi-Way Refineries, Ltd.	Edmonton, Alta.	500
Amherst Oil Refineries, Ltd.	Amherstburg, Ont.	2,500
Arctic Refineries, Ltd.	Lethbridge, Alberta	300
Bell Refining Co., Ltd.	Calgary, Alberta	1,000
British American Oil Co., Ltd.	Toronto, Ont.	6,000
	Montreal East, Que.	12,000
	Moosejaw, Sask.	4,000
	Coutts, Alberta	2,500
Burlington Refineries, Ltd.	Hamilton, Ont.	600
Canadian Oil Companies, Ltd.	Petrolia, Ont.	5,000
Comet Oil Refineries, Ltd.	Point-aux-Trembles, nr. Montreal	2,000
Consumers Co-operatives Refineries, Ltd.	Regina, Sask.	500
Devenish Petroleum, Ltd.	Skiff, Alberta	
Direct Oil Refineries, Ltd.	St. Boniface, Man.	200
Easton Refinery Co.	Easton	300
Gas & Oil Products, Ltd.	Hartwell	1,000
Gold Standard Oils, Ltd.	Wainwright, Alberta	200
Good Rich Refining Co., Ltd	Port Credit, Ont.	2,000
Hi-Way Oil Co., Ltd.	Surrey, B. C.	200
Hi-Way Refineries, Ltd.	Regina, Sask.	
	Moosejaw, Sask.	
	Swift Current, Sask.	
	Rosetown, Saskatoon	
	Prince Albert, Sask.	
	Edmonton, Sask.	
	Weyburn, Sask.	2,150
Home Oil Distributors, Ltd.	North Vancouver, B. C.	1,000
Home Oil & Refining Co., Ltd.	Humboldt, Sask.	300
Imperial Oil, Ltd.	Dartmouth (Halifax) N. S.	17,000
	Montreal, P. Q.	30,000
	Sarnia, Ont.	22,000
	Regina, Sask.	7,200
	Calgary, Alta.	5,000
	Ioco, B. C.	16,000
	Fort Norman, Northwestern Ter.	50
La Salle Petroleum Refinery, Ltd.	East Montreal, P. Q.	2,500
Lion Refining Co.	Calgary, Alberta	750
Lloyd Refineries, Ltd.	Port Credit, Ont.	1,500
Maple Leaf Petroleum, Ltd.	Coutts, Alberta	5,000
McColl-Frontenac Oil Co., Ltd.	Toronto, Ont.	5,000
	Montreal, P. Q.	12,500
New Brunswick Gas & Oilfields, Ltd.	Weldon, N. B.	100
North Star Oil Ltd.	St. Boniface	900
Northern Petroleum Corp., Ltd.	Kamsack	200
Northwest Co., Ltd.	Ft. Norman	100
Oughton Bros.	Turner Valley, Alberta	100
Radio Oil Refineries, Ltd.	East Kildonan	1,200
Regal Petroleum Co., Ltd.	Calgary, Alberta	3,000
Sava Oil Refineries, Ltd.	Windsor, Ont.	1,000
Selkirk Oil Refineries, Ltd.	Carman, Man.	
	Portage, Man.	
Shell Co. of British Columbia, Ltd.	Burnaby	4,000
Shell Oil Co. of Canada, Ltd.	East Montreal	5,500
Soo Refinery, Ltd.	Weyburn, Sask.	150
Standard Oil Co. of British Columbia	Burrard Inlet, nr. Vancouver	2,400
Soo Refinery, Ltd.	Weyburn, Sask.	150
Standard Oil Co. of British Columbia	Burrard Inlet, nr. Vancouver	2,500
Vancouver Oil Co., Ltd.	North Vancouver	1,000
Widney Refineries	Turner Valley, Alberta	150

Cuba

Standard Oil Co. of Cuba	Belot, Havana	5,000

Mexico

Cia. Mexicana De Petrole "El Aguila," S. A.	Minatitlan, Isthmus of Tehuantepec	30,000
	Tampico, North Mexico	56,000
	Atzcapotzalco, nr. Mexico City	15,000
Huasteca Petroleum Co.	Tampico	20,000
Petroleos De Mexico	Tampico	3,000
Pierce Oil Co.	Arbol Grande, Tampico	16,000

Trinidad

Kern Trinidad Oilfields, Ltd.	Trinidad	1,000
Trinidad Central Oilfields, Ltd.	Tabaquite	350
Trinidad Lake Asphalt Operating Co., Ltd.	Brighton	1,000
Trinidad Leaseholds, Ltd.	Pointe-a-Pierre	20,000
Trinidad Oilfields Operating Co., Ltd.	LaBrea	2,000
United British Oilfields of Trinidad, Ltd.	Point Fortin	5,000
West India Oil Co.	Point d'Or	1,000

crudes Venezuela itself is developing a refining industry. At San Lorenzo in the west the refinery of Caribbean Petroleum Co. has been enlarged to a daily capacity of 17,000 bbl. during the past year. At La Salina on Lake Maracaibo, Lago Petroleum Co. has just completed a 7,000 bbl. per day distillation plant, while in the east Standard Oil Co. of Venezuela is engaged in construction of a new plant of 30,000 bbl. daily capacity at Caripito.

Not far off the coast of eastern Venezuela lies the British island of Trinidad with a daily production of over 50,000 bbl. of crude most of which is exported in the form of products. Large additions recently have been made to its two largest refineries, that of Trinidad Leaseholds Ltd. at Pointe-a-Pierre and that of United British Oilfields Ltd. at Point Fortin. In the case of the latter the new equipment has included a crude oil distillation unit and a gasoline stabilization system increasing capacity to 35,000 bbl. daily. The new refinery of Trinidad Leaseholds, Ltd. which was described in detail in WORLD PETROLEUM of May, 1939, is equipped with topping, Dubbs cracking, distillate and vacuum rerun units, an iso-octane installation and a sludge conversion plant. It has a capacity of 30,000 bbl. daily.

Elsewhere in South America the principal activity in the refining field has consisted in enlargements of the plants of Yacimientos Petroleras Fiscales (YPF) in Argentina and the installation of a polymerization plant built by the Alco Products division of American Locomotive Co. In Brazil the government has just closed a contract with Foster-Wheeler Co. for a refinery of 4,000 bbl. daily capacity which will include a Dubbs cracking unit. In Eastern Peru, the Cia. Petrolio Ganso Azul has contracted for a refinery of 1,000 bbl. daily capacity.

Very important developments have taken place during the past few months in the refining situation in the three principal countries of Europe—the United Kingdom, France and Germany. Owing to the censorship imposed on account of the war it is impossible to give details of these activities, but it can be said that in all three countries they include plans for increasing the production of aviation fuel and other products in particular demand for war use.

While the outbreak of hostilities has caused the deferment of refining enterprises planned in several neutral European countries two projects which were well advanced before the beginning of the present conflict are being pushed to completion this year. One of these is the plant of Soc. Anon. Concessionara de Refinacio de Petroleo (SACOR) which is being erected near Lisbon under an agreement by which it will have the exclusive right to supply 50 percent of Portugal's petroleum requirements. The other is the refinery of Rederiaktiebolaget Nordstjernan at Nynashamn near Stockholm which is to have a daily capacity of 6,000 bbl. A Dubbs cracking unit of 1,900 bbl. daily capacity is included in this plant.

A development of importance to Great

SOUTH AMERICA

Company	*Plant Location*	*Daily Capacity (Bbl. crude)*
Argentina		
"Astra" Compania Argentina de Petroleo, S. A.	Campana	5,000
Compania Ferro-Carrilera de Petrolero	Comodoro Rivadavia	8,000
Compania Nativa de Petroleo	Bahia Blanca	2,000
	Campana	11,000
Compania Petrolifera Andina	Province of Mendoza	1,200
"Diadema Argentina" S. A. de Petroleo	South Dock, Buenos Aires	15,000
"El Condor" (Destilerias Argentinas de Petroleo El Condor)	Levalle 27, Avellaneda	450
	Calle Fraga 782, Avellaneda	600
	Avellaneda	1,000
"Itaca" Compania Argentina Para la Elaboracion de Productos Petroliferos, S. A.	Campana	5,000
Lottero, Bapini & Co.	Pineiro	210
Refineria de Petroleo "La Isaura"	Bahia Blanca	1,600
Standard Oil Co., S. A. Argentina	Plaza Huincul	200
	Embarcacion	500
Ultremar, Sociedad Anonima, Petrolera Argentina	Dock Sud, Buenos Aires	3,000
Yacimientos Petroliferos Fiscales (YPF)	La Plata	23,000
	Plaza Huincul	400
	Salta, Vespucio	300
	Mendoza	650
	Santa Fe	9,000
	Campana	3,000
Bolivia		
Yacimientos Petroliferos Fiscales Bolivianos	Sanadita	200
	Camira	200
Brazil		
Distillaria Rio Grandense De Petroleuo, Ltd.	Uruguayanna, Rio Grande do Sul	200
Ipiranga S. A. Cia Braxileira De Petroleo	Rio, Grande, Rio Grande do Sul	1,000
Industrias Reunidas F. Matarazzo	Sao Paulo, S. P.	1,400
Chile		
Johannsen, C. H.	Coquimbo	125
Societe Establecimientos Quimicos De Vina Del Mar	Vina del Mar	174
Colombia		
Tropical Oil Co.	Barranca Bermeja	7,500
Ecuador		
Anglo-Ecuadorian Oilfields, Ltd.	La Libertad	750
Ecuador Oilfields, Ltd.	Cautivo	108
Netherlands West Indies		
Arends Petroleum Maatschappij	Druif, Island of Aruba	22,000
Curacaosche Petroleum Industrie Maatschappij	Emmastad, Curacao	260,000
Lago Oil & Transport Co., Ltd. (of Canada)	St. Nicholas, Aruba	300,000
Peru		
Establecimiento Industrial De Petroleo De Zorritos	Valley of Zorritos	1,000
International Petroleum Co., Ltd.	Talara	16,000
Uruguay		
Administracion Nacional De Combustibles, Alcohol Y Portland (ANCAP)	La Teja	4,500
Venezuela		
Caribbean Petroleum Co., The	San Lorenzo	17,000
Compania De Petroleo Lago	La Salina (Zulia)	7,200
Standard Oil Co. of Venezuela (under construction)	Caripito	30,000

Britain at this time is the addition to Manchester Refinery of a special plant for the production of transformer and white oils. This plant is said to be capable of supplying the ordinary requirements of the British market in transformer oils, amounting to about 17,000 tons yearly, and a considerable proportion of the country's requirements of white oil. Formerly these oils came largely from Russia or Germany.

When the Manchester Refinery was built, in 1938, it included a high vacuum Foster Wheeler distillation unit, a Benzol SO_2 selective solvent and dewaxing plant, a plant for acid treating by centrifuges and a contact clay filtration plant. The oil having been previously solvent treated the additional treatment for producing high grade transformer and white oils is comparatively light, thus saving chemicals and increasing the overall yields. Even with a paraffinous crude a pour point conforming to the stringent B. E. S. A. specification for B 30 and A 30 grades of transformer oil, i.e. below 30 deg. C., can be obtained.

An important addition to refining facilities in the Near East is the construction at Haifa, Palestine, of the plant of Consolidated Refineries, Ltd. The company is a joint enterprise of Anglo-Iranian Oil Co. Ltd. and the Royal Dutch Shell group. The refinery will handle the respective shares of the two interests in Kirkuk oil delivered by the Iraq pipeline. It will have a capacity of about 40,000 bbl. daily.

Still further east, on the island of Bahrein, the capacity of the refinery built by Bahrein Petroleum Co. Ltd., has been raised to 35,000 bbl. daily. A catalytic polymerization plant was put into operation last September. This plant employs the liquid phosphoric acid catalytic process developed by Standard Oil Company of California. Propylene and butylene fractions produced in the cracking and reforming operations are converted into motor gasoline polymers for use in improving the octane number of the refinery gasolines. The plant and auxiliaries are of sufficient capacity to process approximately 3,000 bbl. per stream day of olefin feed cut, from which nearly 1,000 bbl. of butane-free motor gasoline polymers are produced. In Iran further additions have been made to the huge Abadan refinery of Anglo-Iranian Oil Co. Ltd. including two new 20,000-bbl. reforming units for production of high octane fuels and the company is preparing plans for another refinery in the Bandar Mashur area to handle production from new fields being developed in southern Iran.

In India the Attock Oil Company has been engaged in erection of a 4,000-bbl. refinery at Rawalpindi to operate on crude from the Dhulian field. One of its features is a U. O. P. polymerization unit. In the Netherlands Indies further additions have been made to the capacity of the large refineries of Bataafsche Petroleum and Nederlandsche Koloniale Petroleum Mij. and in Australia plans are under way for the erection of a plant of large capacity by an international oil company.

The most significant conclusion to be drawn from a review of refinery construction and expansion during 1939 is that the world refining industry is steadily growing in efficiency as well as in capacity. Great strides are being made in the conversion to useful products of materials formerly wasted, in imparting higher quality and better performance to products formerly regarded as standardized and in acquiring a flexibility in operation that makes possible the adaptation of refinery output to the specific requirements of industrial progress.

© Philips Lamps

ALLOY DEVELOPMENT Has Made Possible Many Recent Refining Operations

By B. B. Morton, Development & Research Div., International Nickel Co.

THE evolutionary and revolutionary changes taking place in the art of petroleum refining present a kaleidoscopic appearance to one observing from the outside. Equipment gleaming in its first coat of paint is pronounced obsolete, due to newer discoveries in the art, and whole plants have been discarded in the path of progress.

The changes occurring are the result of the struggle for better and better products and the control of the production of these products by catalytic and other means.

Each major development in the art of refining has apparently made some new demand on metals, and, surveying a large refinery as a whole, practically every commercially available metal will be found in use, as well as some rarer metals such as tantalum and platinum.

The art of refining consists in adding and removing heat and contacting with suitable reagents or catalysts. In the matter of adding and removing heat, coils and bundles of tubes are used. The contacting with reagents and catalysts usually takes place in vessels.

In preparing lubricants, controlling reactions and fractionating certain gases, heat is removed to the varying degrees with attending drop in temperature. Temperatures of —75 deg. F. are commonly encountered, and an alloy largely used for equipment to operate at this temperature is the 2¼–2½ percent nickel steel referred to in Table I and illustrated in this article. For valves, valve parts, exchanger parts, return bends, pump parts, etc., a cast or wrought three percent nickel steel is widely used. A chrome-molybdenum steel corresponding to SAE-4130 or 4140 is also used as valve and valve parts, as well as for fittings.

Temperatures of —150 deg. F. and —200 deg. F. are appearing in refining circles, and attention is becoming directed to the austenitic ferrous alloys and to non-ferrous alloys. Table II gives some impact values of Inconel, Nickel, Monel and 18—8 at sub-zero temperatures.

The resistance to impact has become accepted as the basis for usefulness of a material at sub-zero temperatures, since this appears to be the property most sensitive to reduced temperatures. Ten to twenty foot-pounds are generally considered the minimum to which the impact value may drop for the material to be satisfactory. That properties other than resistance to impact may be improved at lower temperatures is shown in an illustration that accompanies this article.

Method of applying corrosion resistant facing to steel plates, and (inset) Croloy Bonded Plate with alloy veneer obtained by welding several thin sheets of chromium alloy to base plate of carbon steel.

The addition of heat has presented problems, since metals become progressively weaker as their temperature is raised. At elevated temperatures the metals do not fail by sudden rupture at a stress above a given level, but tend to creep or flow, with resulting thinning of parts and subsequent failure.

The problem of sulphur atack is usually associated with the heating of petroleum and many of its products.

Chromium imparts to steel a resistance to sulphur attack. Molybdenum improves its resistance to creep up to rather elevated temperatures. The result of these combined facts has led to the wide adoption of tubes of a steel containing from 2—9 percent of chromium with about 0.50 percent molybdenum. The 4-6 percent chrome —0.50 molybdenum tubes are probably the most widely used chrome alloy tubes for heating coils at the present

time. Where sulphur attack is not a major problem, the chromium is omitted and carbon-molybdenum tubes are used.

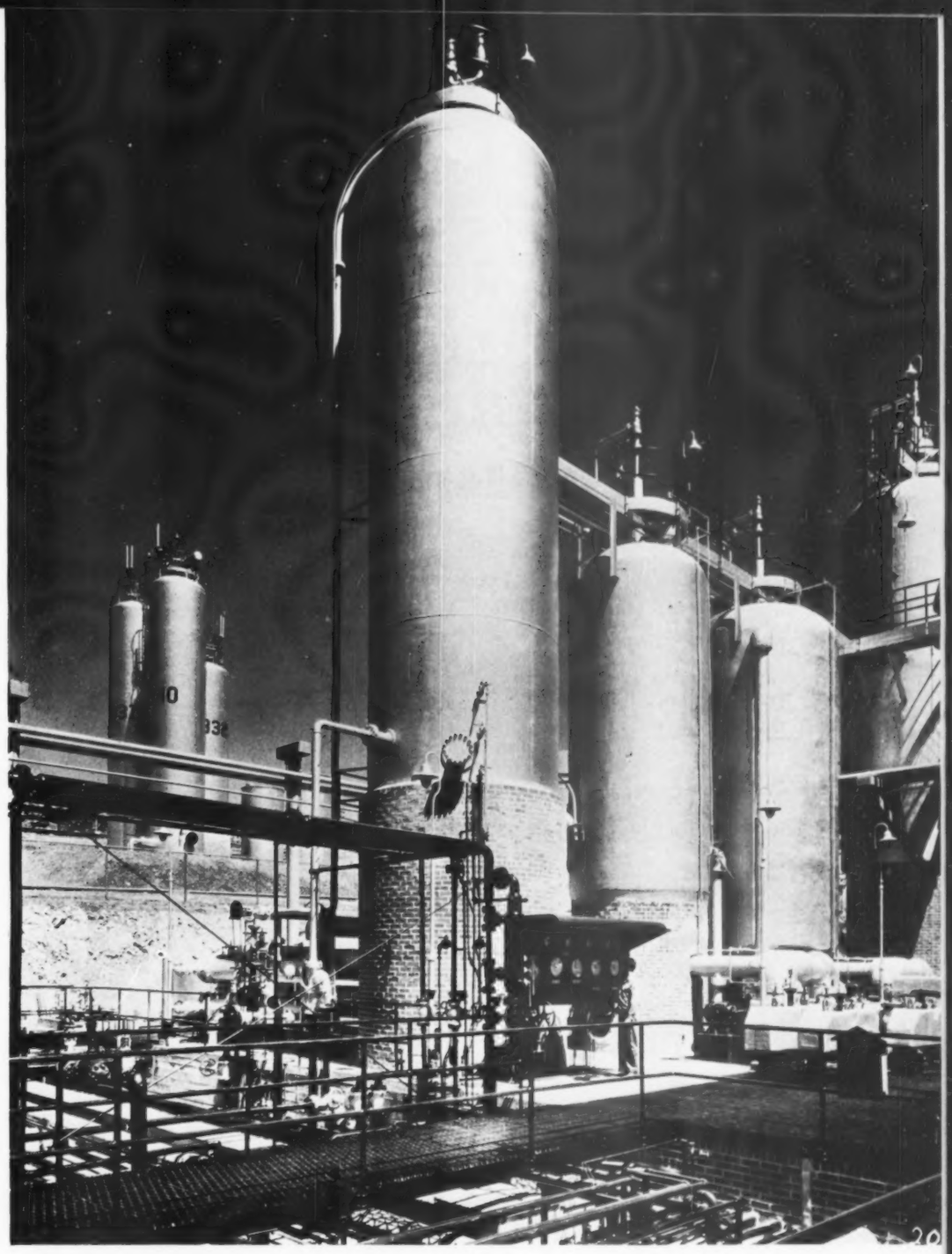
Tubes of 18 percent chromium —8 percent nickel have found limited use in heating coils. The tubes are apparently immune to the most vigorous attack by sulphur, and, when so operated that the metal walls do not exceed 1200 deg. F., give excellent service. Services of 50,000 hours have been reported for 18—8 tubes, and this figure has probably been exceeded.(1) The popularity of tubes of 18—8 has suffered due to their tendency to fail suddenly and violently without a warning bulge. The reason for this type of failure appears to be due to incipient failure starting at the outside and progressing inward. This type of failure suggests fatigue cracks developing under fluctuating heat input.

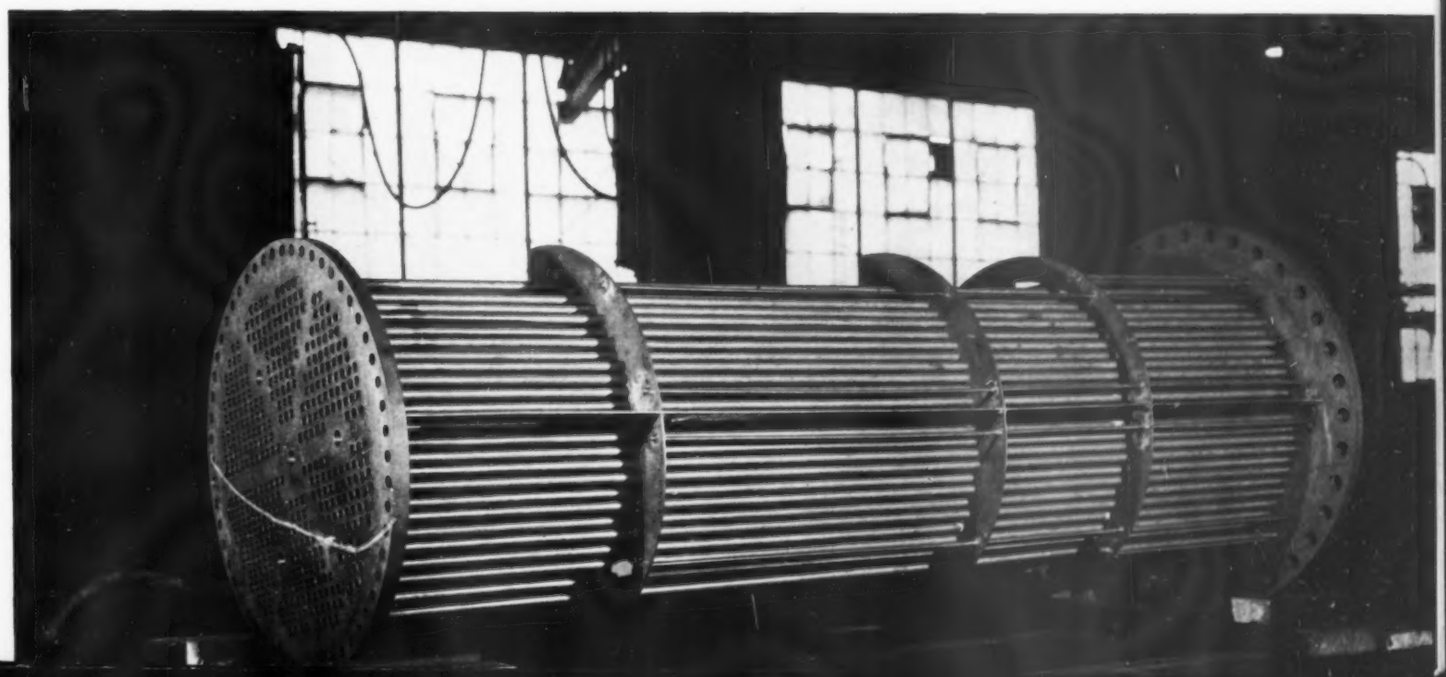
The 4—6 percent chrome—0.50 percent molybdenum type of alloy is also widely used in downcomer and other transfer lines. The massive housings and parts of return bends on fired coils make use of nickel-chromium and chromium-molybdenum steels desirable.

The heat resisting alloys used to support tubes in furnaces are generally castings of high chromium—high nickel alloys. An alloy of 28 percent chromium — 12 percent nickel appears to be a favorite for this service. However, other compositions are used, including 25 percent chromium — 20 percent nickel. In the cooler sections of the furnace, cast irons of various compositions are used. Ni-Resist, an austenitic cast iron containing 15 percent nickel, six percent copper and two percent chromium, is in use as tube support material where the temperatures average about 1500 deg. F. The low oxidation and growth rate led to the adoption of Ni-Resist for this service.

The reactions that take place at elevated temperatures and pressures have led to the

(1) See "Corrosion Protection of Refinery Equipment" by J. A. Jamison, Proceedings 19th Annual Meeting A. P. I. 1938 (Vol. 19 (III) 1938), for histories of 18-8 and other tubes.





Right, 2½ percent nickel steel used for pressure vessel operating at minus 50 deg. F., and below tube bundle of 70/30 copper-nickel.

TABLE I

Impact Values of 2.25- to 2.50-Percent Nickel Steels and Other Nickel Steels

Type	Partial Analysis: Carbon (Percent)	Partial Analysis: Nickel (Percent)	Partial Analysis: Copper (Percent)	Physical Properties: Ultimate Tensile Strength (Lb. Per Sq. In.)	Physical Properties: Yield Point (Lb. Per Sq. In.)	Physical Properties: Elongation in 2 In. (Percent)	Physical Properties: Brinell Hardness No.	Charpy Impact Values (Foot-Pounds): Room Temp.	Charpy Impact Values (Foot-Pounds): —50 Deg. F.	Charpy Impact Values (Foot-Pounds): —75 Deg. F.	Charpy Impact Values (Foot-Pounds): —100 Deg. F.	Charpy Impact Values (Foot-Pounds): —150 Deg. F.	Charpy Impact Values (Foot-Pounds): —200 Deg. F.	Note
[1] 2.25 per cent nickel steel	0.20-0.30	2.00-2.50	.....	80,000	55,000	40	.....	35	21.8	.....	.....	.....	.....	Stress-relieved at 1,200 deg. F. Commercial plate. Keyhole notch.
[2] Heat No. 11955	0.08	1.99	.....	61,500	47,000	40.5	121	63	.....	62	52-63	39-40	24-30	Laboratory study. Aluminum-treated. Keyhole notch.
[2] Heat No. 11956	0.09	1.52	0.70	64,900	51,000	36.8	131	56	.....	56	40-55	23-32	26-30	Laboratory study. Aluminum-treated. Keyhole notch.
[4] Nickel iron	0.03	3.96	.....	.....	.....	.....	150	.....	.....	.....	.....	96 (—160 deg. F.)	41 (—220 deg. F.)	Keyhole notch. Normalized at 1,600 deg. F.

[1] Based on work reported by Aldridge and Shepherd, "Nickel Steel at Low Temperatures," Metals & Alloys, June and July, 1936.
[2] Laboratory studies, The International Nickel Co., Inc.

use of very thick walls for vessels. Part of this thickness has been sacrificed to corrosion. The tendency today is to use vessels lined with corrosion resistant materials, and there are to be found vessels lined with a surface of nickel, Monel, high chromium material, and 18 percent chromium—8 percent nickel alloy. Unique methods of cladding steel have been developed. Inconel (80 percent nickel—13 percent chromium), Nickel and Monel (69 percent nickel—29 percent copper) sheets are clad to steel by a direct rolling process worked out by the Lukens Steel Company. Facings of a wide variety of alloys are applied to steel by the M. W. Kellogg Company under the name of "Kelcaloy" which finds many uses in the refinery. The A. O. Smith Corporation has developed a method of welding alloy sheets to steel plates to provide a material from which vessels can be formed. The Babcock & Wilcox Company make use of a resistant facing consisting of thin layers of chromium alloy resistance welded to a base plate of carbon or carbon-molybdenum steel. A nickel sheet is applied over the base metal to prevent carbon migration. Linings [2] [3] to existing vessels or to vessels under construction are applied by plug welding. An accompanying illustration shows the head of a vessel to which a lining of Monel has been applied by plug welding. Lined vessels are used as reaction chambers, exchanger shells, accumulators and for other purposes.

Linings are also applied to important overhead and transfer lines: 18—8 and chromium alloys are used to protect against sulphur attack at elevated temperatures. Monel and brass are used at temperatures below the condensation point of water to protect against attack by hydrochloric and organic acids. Monel also finds use to protect certain parts against phosphoric attack in the steaming-back operation carried out in certain polymerization plants. The 18 percent chromium—8 percent nickel—3 percent molybdenum alloys are highly resistant to naphthenic, phosphoric and organic acids, and are used to protect parts as well as for whole pieces of equipment.

Condensing equipment plays an important role in refining. Tubes of Admiralty Metal are the most widely used of non-ferrous alloys. The alloy suffers dezincification in certain locations, and has been somewhat replaced with red brass, which in turn is more subject to sulphur attack, and by the 70 percent copper—30 percent nickel tubes, with and without additions of low percentages of zinc and tin. The copper-nickel alloy is especially used where brackish or contaminated sea water is the coolerant. Naval Bronze appears to be the popular material for tube sheets. Ni-Resist cast iron is also used as the material for channels and heads of tubular condensers through which sea water is passed.

Bolts in submerged cooling coils are readily attacked when sea water is used. To resist this attack, bolts of Muntz Metal or other high copper alloys and of Monel are used. Long service from these bolts is obtained, since they are normally more resistant to sea water and are also galvanically protected by the cast iron flanges in which they serve. The added attack on the flanges is negligible.

One of the most striking features of a refinery is the vast number of pumps. When one considers, however, that the water and fire systems of a fair-sized city as well as facilities for handling petroleum and its liquid products are contained in a large refinery, it is not so remarkable that pumps of such varieties of sizes, shapes and design are present.

The metallurgy of pump design and maintenance has long occupied the attention of engineers,[4] since wear, abrasion, corrosion and high stresses are often encountered. Some of the largest pumps in refineries are used to provide water. These pumps are largely centrifugal and when handling salt water make use of Monel, 18 percent chromium—8 percent nickel alloy, or the reverse analyses with nickel predominating. In fresh water, use is made of bronze or alloy cast irons. The latter is popular where the water contains silt.

Hot oil pumps make use of 4—6 percent

[4] A. E. Harnesberger on "Use of Metals in the Petroleum Industry", American Institute of Mining and Metallurgical Engineers' Symposium, February, 1935.

[2] "Field Lining of Refinery Vessels with Stainless Steel Sheets or Strip" by K. E. Luger, Stainless Steel Division, Carnegie-Illinois Steel Corporation, Houston, Texas.

[3] "Field Installation of Chromium Sheet Linings in Pressure Vessels" by J. T. Shaler, Standard Oil Co. of Calif., Proceedings 9th Mid-Year Meeting A. P. I., Vol. 20M (III) (1939).

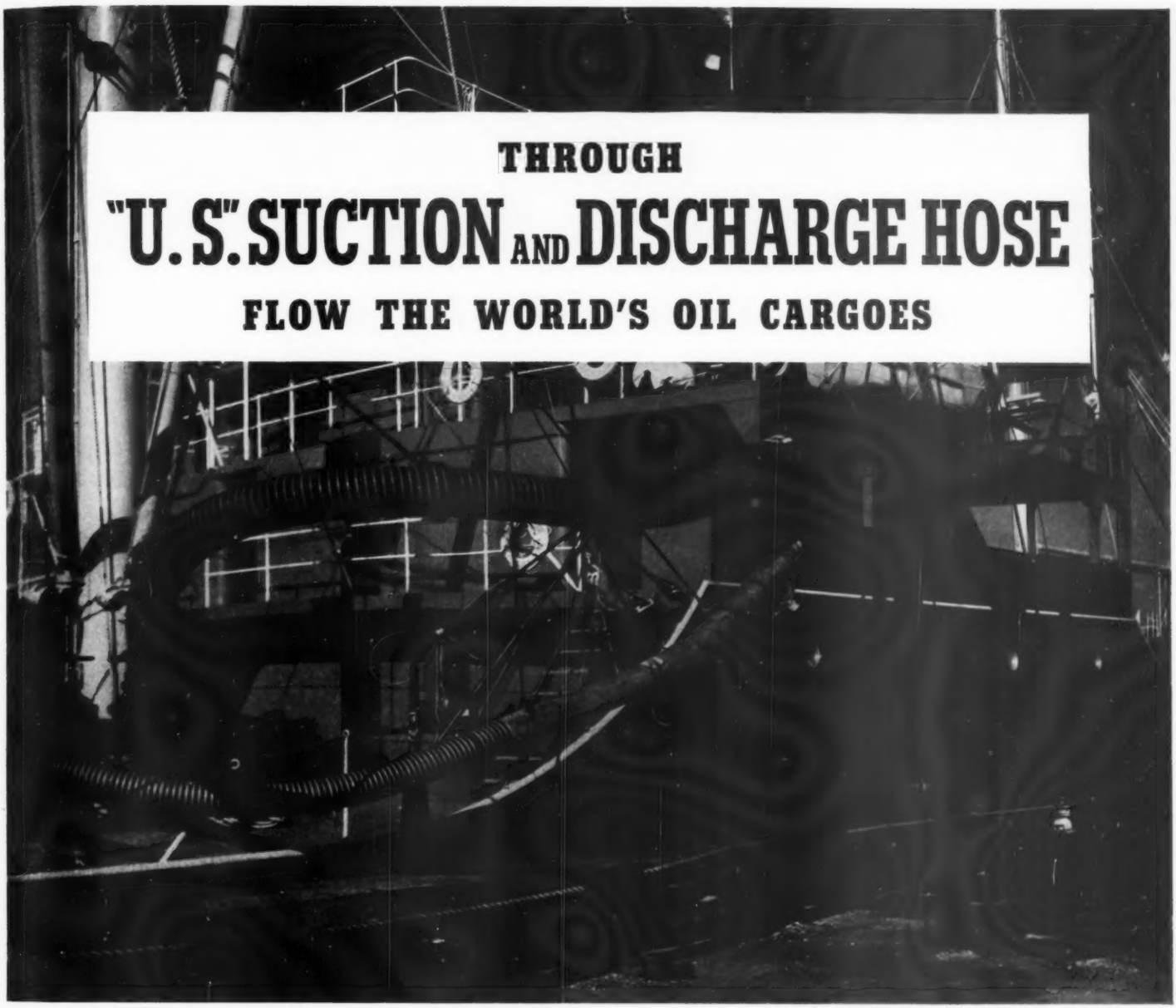
TABLE II

Impact Values of Inconel, Monel, and Nickel at Sub-zero Temperatures*

Material	State	Charpy Impact Values (Foot-Pounds) 45-Deg. V-Notch: Room Temp.	-112 deg. F.	-310 deg. F.
Inconel (80% nickel, 13% chromium, 7% iron, carbon, etc.)	Hot rolled	236	206	187
	Cold drawn—center	33**	34**	28**
	Cold drawn—outside	40**	38**	33**
	Annealed, 1,600 deg. F.	128	126	112**
Monel (69% nickel, 29% copper).	Hot rolled	219	213	196
	Cold drawn—center	161	143	131**
	Cold drawn—outside	135	129	122
	Annealed, 1,400 deg. F.	215	219	207
Nickel	Hot rolled	135	236	227
	Cold drawn—center	185	205	210
	Cold drawn—outside	190	236	208
	Annealed, 1,400 deg. F.	216	236	234

		Impact values of 18-8*** Room	Izod Values -85 deg. F.	-292 deg. F.
18-8 (18% chromium, 10% nickel)	Quenched from 2000 Deg. F.	114	118	100

* Research Laboratory, The International Nickel Co., Inc.
** Specimen completely fractured. All other values are for only partly broken specimens.
*** "Nickel Alloy Steels", a publication of The International Nickel Co., Inc., p. 38, Section V, Data Sheet No. 1.



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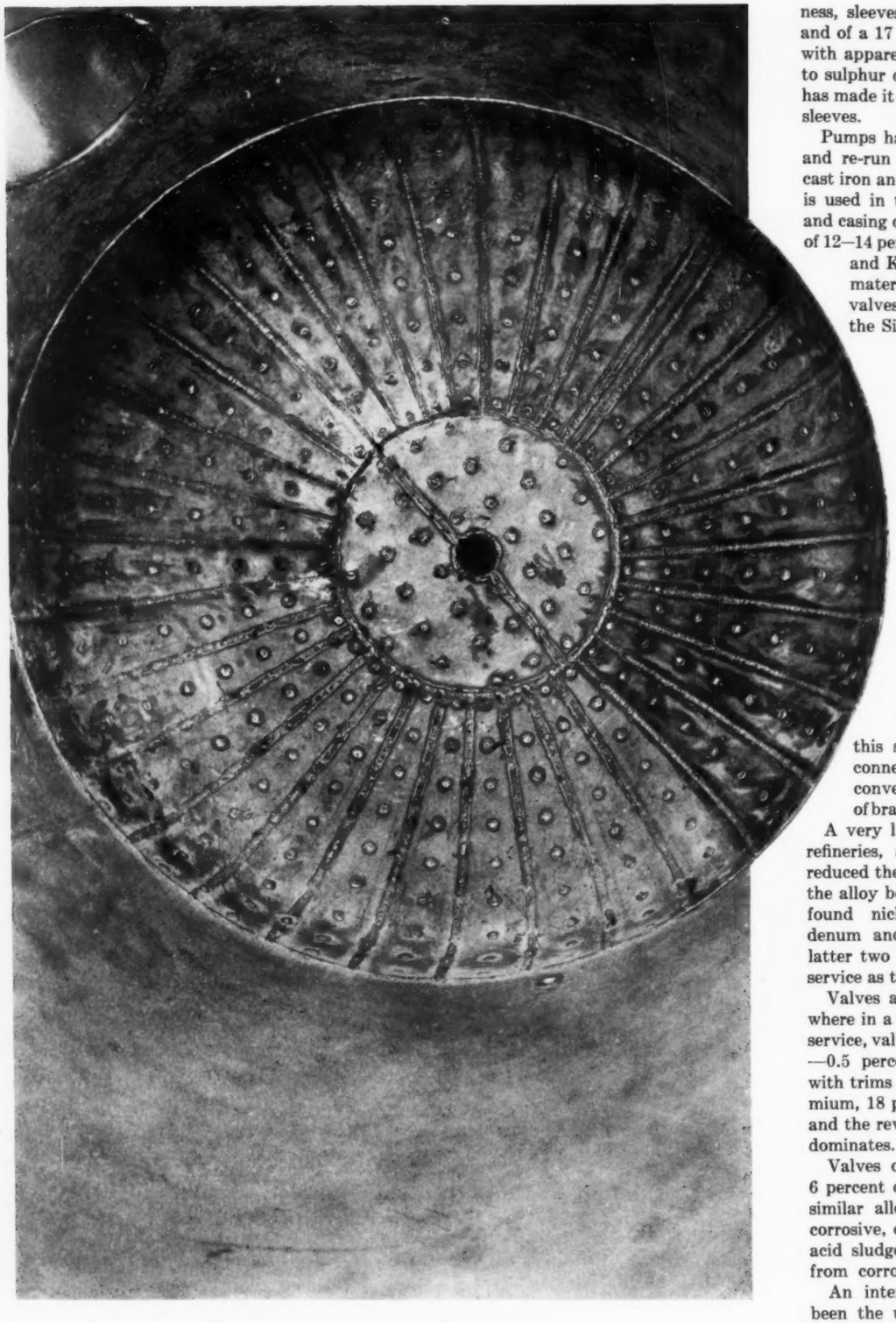


Monel clad head of accumulator showing method of installing liner by plug welding. Courtesy Black, Sivalls and Bryson, Inc.

chromium—0.5 percent molybdenum alloys in blocks, liners and impellers. The 18—8 enters hot oil centrifugal pumps as the material for shafts and impellers. The materials in hot oil pumps are indicated by the sulphur content of the materials handled. The plungers of hot oil pumps present a problem, as abrasion by the packing is a factor in the destruction of these plungers. High chromium alloys containing small additions of nickel, tungsten and molybdenum are reported used in this service. To obtain high surface hardness, sleeves of heat treated alloy cast iron and of a 17 percent chromium alloy are used with apparent success. The higher resistance to sulphur of the 17 percent chromium alloy has made it the more popular material for the sleeves.

Pumps handling reflux, acid treated stocks and re-run materials make use of Ni-Resist cast iron and brass liners and parts. Ni-Resist is used in this service as both the impeller and casing of centrifugal punps. Pump rods of 12—14 percent chromium steel, 18–8, Monel and K Monel are used in handling the materials mentioned above and also valves of Monel and stainless steels of the Sims or Durabla types have added to the efficiency of reciprocating pumps in this service.

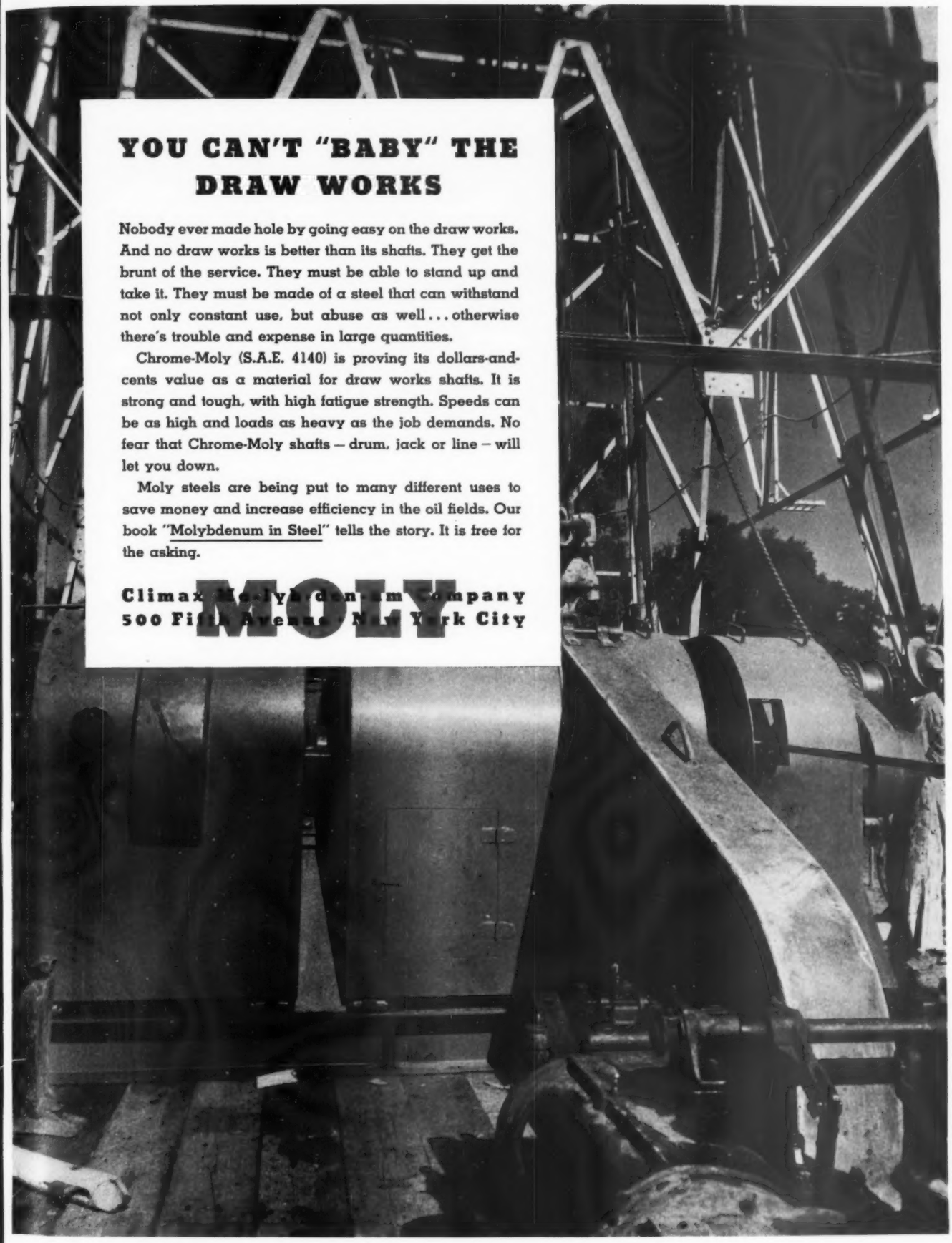
For handling sulphuric acid, pumps are equipped with brass or bronze liners and parts. Monel rods are widely used in this service. Similar pumps are used in connection with acid sludge and the conveying lines for this material are often of brass and in some few cases of Ni-Resist.

A very large number of bolts are used in refineries, although welding has somewhat reduced the number of flanged joints. Among the alloy bolts in lines and on vessels will be found nickel-chromium, chromium-molybdenum and chromium-tungsten steels. The latter two are popular for high temperature service as the result of low creep rates.

Valves and cocks are to be found everywhere in a refinery. For high temperature oil service, valve bodies of 4—6 percent chromium —0.5 percent molybdenum steel are used with trims and stems of 12—14 percent chromium, 18 percent chromium, 8 percent nickel and the reverse analyses in which nickel predominates.

Valves of Ni-Resist (15 percent nickel—6 percent copper—2 percent chromium) and similar alloys of cast iron are used where corrosive, cool materials are handled such as acid sludge, re-run material and overheads from corrosive stocks.

An interesting application of alloys has been the use of Monel and stainless steels (18—8) as swing pipe cables in storage tanks. These cables serve to keep the suction pipe above the water level in the tank. Since the introduction of water may play havoc, these cables have an important function and more than justify their cost. Some of these alloy cables are reported in good condition after about ten years exposure to corrosive vapors and liquids.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ALKYLATION'S PLACE
in Refining Industry

Growing Demand for High Test Aviation Fuel Has Directed Special Attention to This Relatively Simple Method of Producing Iso-Octanes — Possibilities and Limitations.

HUGE amounts of iso-butane available in the natural gasoline industry and the readiness with which waste refinery gases react chemically have served to put an active speculative emphasis on the term alkylation and its commercial significance to the refining industry.

What is alkylation? How is it carried out? What justifies it? Will it displace polymerization? These and many other questions have been asked by executive and engineer alike in an effort to analyze this new development and assign it a place in the economic structure of special processes which contribute materials for the manufacture of premium motor and aviation fuels.

The literature on the synthesis of iso-octane by alkylation is fragmentary and authorities agree that the surface has barely been scratched. Moreover, no detailed description of a commercial process has been released, but enough facts are available to permit an estimation of the essential steps in alkylating and a preliminary appraisal of its economic significance.

The word "alkylation" is used by chemists to describe reactions where alkyl groups are substituted for hydrogen atoms in other compounds, usually ring compounds where the carbon atoms are linked together in the form of a geometrical figure. The propane and butane hydrocarbons found in natural gas, if lacking an atom of hydrogen, become propyl and butyl radicals and appear in this form in combination with water as propyl and butyl alcohol respectively. The presence of these radicals in alcohols gave them the name "alkyl radicals," the word alkyl being coined from the first three letters of the German spelling of the word alcohol plus the "yl" ending.

Alkyl radicals do not exist in a free state, but first cousins to them which exist as gases are the ethylene, propylene, iso-butylene and normal butylene found in refinery gases from cracking operations. When refinery gas with all of the gases and vapors it contains is treated with heat and pressure, with or without a catalyst, many of the compounds join or associate together to form polymers, and such a procedure is spoken of as polymerization.

On the other hand, if only the iso-butylene in a refinery gas is caused to react with iso-butane from natural gas, iso-octane is formed directly instead of a mixture of polymers. This is spoken of as alkylation although opinions differ as to whether it is truly so. Normal butylene from refinery gas will also react with iso-butane but the product is not iso-octane, but a substance resembling it.

There are other ways of making iso-octane which are not considered to be alkylation processes, but special forms of polymerization. These comprise what is known as selective catalytic and hot acid polymerization. To clarify the discussion which follows it can be said that the essential differences between the various polymerization processes for the production of iso-octane, and alkylation with the same end in view are:

1—Selective catalytic polymerization utilizes the butane-butylene overhead fraction from a cracked gasoline stabilizer to which is fed a stock substantially free of propane. The stock sent to the catalytic polymerization unit is a mixture of iso and normal butylene along with iso-butane and normal butane, which yields iso-octene and other polymers, the iso-octene being hydrogenated to iso-octane.

2—Hot sulphuric acid polymerization utilizes only the iso and normal butylene fractions in refinery gas to obtain iso-octene and interpolymers which are hydrogenated to obtain a yield which is predominantly iso-octane.

3—While cold sulphuric acid alkylation is distinctive in that the reaction is thought to be more truly alkylation in that iso-butylene substitutes or displaces hydrogen in iso-butane to form directly iso-octane and small amounts of other alkylates.

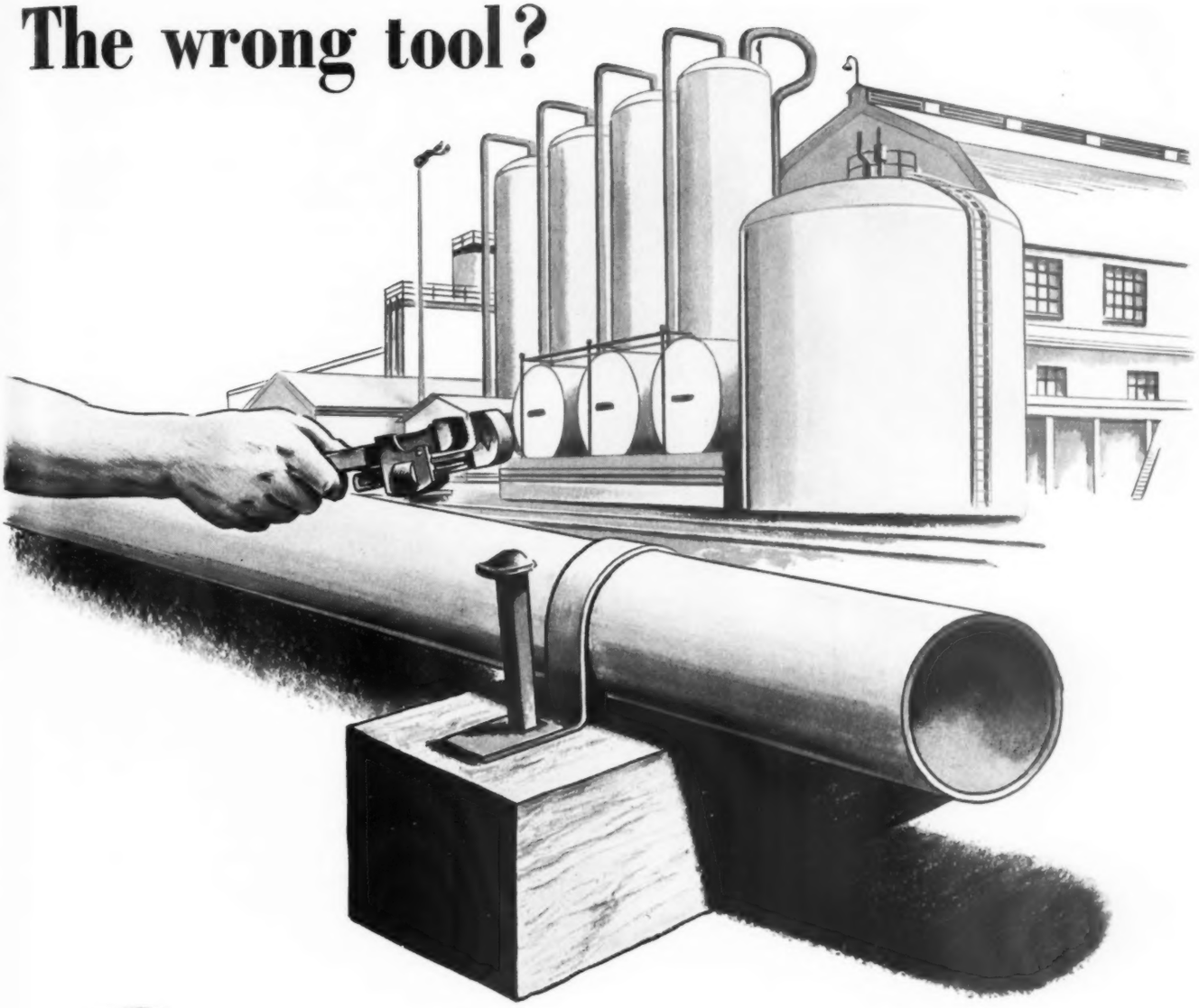
The fact that cold acid alkylation makes iso-octane without the necessity of hydrogenation and utilizes iso-butane from natural gas to almost double the yield has served to stimulate interest as to the nature of the process. The Shell Company of California and The Texas Company are already manufacturing iso-octane by this method and indications are that licenses have been issued to other concerns.

According to reliable sources about 1.2 parts by weight of iso-butane is mixed with one part by weight of butylenes, the mixture cooled to between 45 deg. to 60 deg. F. and brought into violent contact with 98 percent cold sulphuric acid. After the initial contact chilling is again resorted to, to carry off the heat of reaction, and the acid with the reacted butylenes and partially reacted iso-butane is sent to what might be termed contact tanks in series or in parallel where the acid and its products are recycled to increase the yield of alkylate. During the contact period any unreacted iso-butane is recycled to increase its concentration in relation to the incoming butylenes. It is reported that this concentration soon reaches a ratio of 100 to 1.

Each contact stage is kept cold, and finally the acid and alkylate are separated by gravity, the spent acid being brought up to strength again and the alkylate sent to a fractionating column. Any residual iso-butane at the last stage is sent to a refractionating column where impurities are removed and the iso-butane sent back for mixing with fresh charges of butylenes.

In the alkylate fractionating column three distillates are recovered. The overhead which is iso-octane represents about 92 percent of the yield. It has an endpoint of about 310 deg. F. and a good boiling range. A side-cut representing about two to four percent of the alkylate yield has an end-point of about 400 deg. F. and can be used in motor fuel blending. The fractionator bottoms have an endpoint of around 600 deg. F. and can be used in power kerosene and Diesel oils.

The wrong tool?



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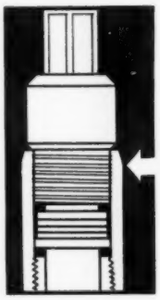
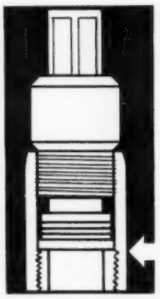
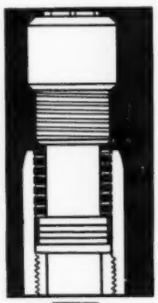


2 When the liner strikes bottom (or when the liner weight is supported by the hanger), the weight of the drill pipe is taken by the ball thrust bearing (arrow) which *automatically* removes the weight from the releasing thread.



3 As the run-in string is rotated, the floating nut, driven by the squared mandrel, unscrews from the liner. It is free to move up the mandrel as the thread unscrews, thus *automatically* eliminating "bind" on the threads. Meanwhile, the liner is held firmly in place by the weight of the run-in string applied through the ball bearing thrust washer device. *This helps to assure positive release whether setting heavy or unusually light equipment.*



• There are other important features, too, such as the tail pipe connection and built-in pack-off for cement jobs, etc. Send for descriptive bulletin that gives the complete details!

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Once the process is in balanced operation the amount of sulphuric acid used is reportedly small although the volume recycled during the cold contact stages is huge. Investment and operating costs are not yet known, but the attractiveness of alkylation is likely to be limited to refineries having suitable cracked gases, a source of cheap iso-butane and facilities for acid recovery.

In that alkylation arrives at the same product (iso-octane) sought by other processes, their mode of operation by way of comparison is of interest. Prominent among these developments is the hot acid polymerization process developed by the Shell Company several years ago.

By this method iso-octene is prepared by the polymerization of iso-butylene in hot sulphuric acid, along with interpolymers formed from normal butylene. Both of the hydrocarbons used as charging stock are derived from the fractionation of Dubbs distillate. The liquefied iso and normal butylenes are mixed with 67 percent sulphuric acid at a temperature of about 175 deg. F. and the resulting mixture, or emulsion, allowed an additional reaction period in contact or time tanks. From the time tanks the acid mixture passes to a separator where the acid and polymers separate, the partially-spent acid being sent back to the reactor to pick up more hydrocarbons.

From the acid separators the polymers go through a soda neutralizing system, a preheater, and then to a fractionating column where any residual gas is separated overhead while the bottoms, consisting of a mixture of iso-octene and interpolymers, are freed of sulphur and sent to the hydrogenation unit.

In hydrogenating the iso-octene it is first vaporized and then mixed with hot hydrogen gas, the mixture passing into a catalytic converter at about 390 deg. F. The catalyst used consists of nickel impregnated in porcelain. After passing through the catalytic converter the hydrogenated iso-octene, which is now iso-octane, along with the hydrogenated interpolymers, are condensed and sent to storage. The nickel catalyst can be reactivated by oxidizing with air and then reducing with hydrogen. One thousand gallons of iso-octane, it is reported, are produced by each pound of catalyst between reactivations. Iso-butylene can also be polymerized to iso-octene with cold sulphuric acid, but the yield is low because normal butylene cannot be utilized as well.

In the selective catalytic polymerization process, iso-octene along with interpolymers are formed by utilizing the iso and normal butylenes and iso-butane overhead from a cracked distillate stabilizer. The liquefied charging stock is first given an alkaline wash to remove sulphur, which would poison the catalyst, and then preheated. The sulphur-free charge is then passed through a solid phosphoric acid catalyst where the conversion to iso-octene and other polymers takes place at about 325 deg. F. and 700 lbs. pressure.

From the catalytic converters the charge passes through a fractionating column where any butane is taken overhead while the bottoms are sent to another fractionating column where iso-octene is taken overhead and the heavier polymers removed as bottoms. In a cycle similar to that described for the hot acid process, the iso-octene is mixed with hydrogen, and passed through catalytic converters to obtain iso-octane.

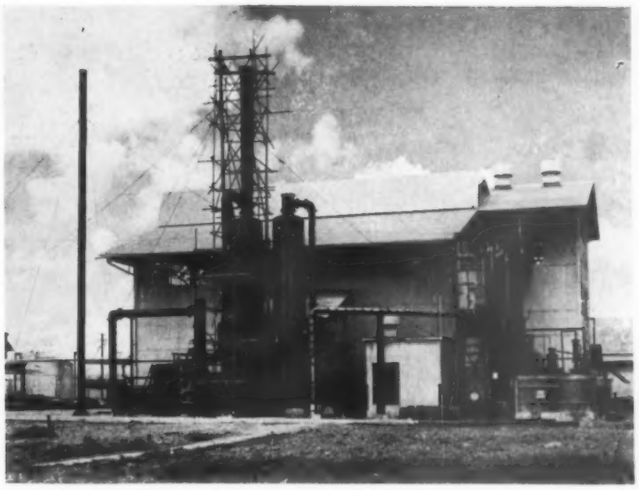
A natural reaction to the foregoing process descriptions would be: Why has so much emphasis been placed on the manufacture of iso-octane? Has this material advantages not possessed by other petroleum distillates? To the first question the answer is: Chiefly to supply the need of aeroplanes, commercial and military, with 95 to 100 octane fuels which perform in high speed engines of huge power output per pound of weight. Ordinary fuels without special treatment cannot function properly due to the high compression pressures required. The use of large amounts of lead tetraethyl is restricted because of its toxicity and because of the accumulation of lead compounds on valves and piston rings. This has led to a search, not only for improved anti-knock characteristics in base stocks used in blending, but for blending materials of high anti-knock value.

In answer to the second question, iso-octane is superior to petroleum distillates because it is the highest in anti-knock quality, being at the top of the octane scale headed by itself. In addition it is completely stable chemically, is susceptible to further treatment with lead tetraethyl, and blends perfectly with base stocks and volatile fractions from natural gasoline such as iso-pentane. Its nearest competitor is di-isopropyl ether.

It is interesting to note that the maximum horsepower demand on an aeroplane engine occurs at the take-off. With the expansion of commercial air travel and military requirements emphasis is being placed on larger equipment with greater pay load capacity and cruising range, higher air speeds and stratosphere flying. These and other factors have led to radical departures in engine design. When Lindbergh flew the Atlantic on May 20, 1927 his aeroplane was equipped with a nine-cylinder Wright Whirlwind J–5 220 h.p. motor. The engine weight was about 2.25 lbs. per horsepower, and the octane value of his fuel about 70. In contrast, the latest nine-cylinder Wright Cyclone engine is rated at 1,100 h.p. at take-off and weighs 1.15 lbs. per horsepower. Many 1,500 h.p. aeroplane engines are now in use and it is expected that about 2,000 h.p. units will soon make their appearance.

Commercial requirements have brought into use huge 42 passenger land planes of the Douglas DC-4 type, while trans-oceanic lines have introduced the Clipper ship. In 1935 the first China Clipper had a gross weight of 52,000 lbs., a still air cruising range of 3,200 mi. at 130 m.p.h. without refueling, a gross horsepower of 3,320 and a wing span of 130 ft. In 1937 the size of the Clippers had grown to a gross weight of 63,000 lbs., a still air cruising range of 5,000 mi. at 156 m.p.h. without refueling, a gross horsepower of 4,000 and a wing span of 157 ft.

A flying boat projected for 1940 is expected



CHEMICO Sludge Conversion Plant of Trinidad Leaseholds Limited, Pointe-a-Pierre, Trinidad. This plant produces clean 98% acid from refinery sludge. Formerly oleum was imported at great expense for the purpose of fortifying acid restored in their concentrators.

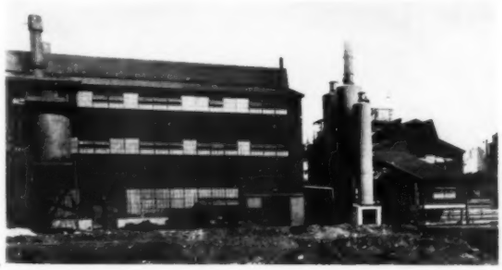
ALKYLATION

requires a MODERN ACID-RECOVERY PLANT

HIGH recovery from the spent acid and a thoroughly dependable fresh acid supply are first essentials to the success of the alkylation process.

CHEMICO has specialized in Refinery Acid Recovery Plants for twenty years and has developed processes to meet all present requirements. Six years of successful operation have proven that the CHEMICO Sludge Conversion Process is the most economical and efficient for large-scale acid recovery, though CHEMICO Acid Separating and Concentrating Plants still satisfactorily meet the requirements of smaller acid users.

If you are considering the installation of an alkylation plant, we shall be glad to consult with you regarding the utilization of our Sludge Conversion Process for the production of clean 98% or fuming acid from alkylation spent acid. Two recent highly successful CHEMICO Sludge Conversion Plants are shown in the illustrations.



CHEMICO Sludge Conversion Plant at the Philadelphia Refinery of the Atlantic Refining Company. This plant produces 98% and 105% sulphuric acid from a variety of refinery sludges that differ widely in chemical and physical qualities.

CHEMICO offers a complete world-wide consulting, designing and erecting service, covering the processing scheme, equipment, structures, and training of the operating crew for delivery of the plant ready for full-capacity operation. All contracts are based upon conservative recommendations, and acceptance is asked only after test-proven fulfillment of every promise.

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